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CHEMISTRY OF AGRICULTURE.

J. H. Bailey

THE

CHEMISTRY OF AGRICULTURE:

OR

THE EARTH AND ATMOSPHERE AS RELATED
TO VEGETABLE AND ANIMAL LIFE.

WITH NEW AND EXTENSIVE ANALYTICAL TABLES.

By DAVID CHRISTY,
Author of Letters on Geology, etc.

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PREFACE.

THE author has often urged others, better qualified than himself, to prepare a small tract, showing the relation which Vegetables and Animals bear to each other, and to the sources whence they derive the elements of their growth. The task, however, remaining unexecuted, he has undertaken its performance himself; but with what success, the public must judge.

In the preparation of the work, free use has been made of some ten or twelve authors, whose names appear, occasionally, throughout its pages. One principal aim has been, to state all that is known on each point, from the investigations of chemists, up to the present moment; consequently, less use has been made of LIEBIG, and the other pioneers in Agricultural and Animal Chemistry, than of the more recent writers on these sciences.

The Tables of Chemical Analyses have been prepared with great care, from the best authorities, and the hope is entertained that they will prove of great value to the agriculturist, as well as to the student. The temperature, in all cases, is according to Fahrenheit.

OXFORD, OHIO, January, 1853.

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THE
EARTH AND ATMOSPHERE,
AS RELATED TO
VEGETABLE AND ANIMAL LIFE.

CHAPTER I.

SOURCES OF SOILS.

A FEW simple elements, entering into combination with each other, in an almost infinite variety of forms and proportions, serve to make up the great mass of the mineral, vegetable and animal kingdoms. This fact has been revealed to us by the patient and laborious researches of the chemist. But why the same elements are taken up from the earth and atmosphere, by one plant, in such proportions as to be *nutritious*, and essential to the sustenance of animal life; while another plant, growing in the same locality, absorbs these elements from the same soil and air, in proportions that render it *poisonous*, and destructive of animal life, is a question that cannot be answered by the most profound chemical research. Such mysteries are known only to that Infinite Wisdom which has ordained the laws of life, and given to each herb and tree the power, only, of "yielding seed after its kind." For this reason, the investigations in Agricultural Chemistry must, necessarily, be limited to the determination of the results of the action of vegetable life upon the elements that come within its control.

To present to the student of Agricultural and Animal Chemistry, in as brief a space as possible, such facts as may best serve to exhibit the earth and atmosphere in their rela-

tions to vegetable and animal life, is the object of this little volume. This task, it has been found, can be most easily accomplished, by condensing, into a series of Tables, the results of the labors of chemists, in their analyses of the atmosphere, and of mineral, vegetable, and animal substances. The compilation of these tables leaves little else to be done, than to give definitions of the terms used, and explanations of the leading characteristics of the elements named.

All soils being derived from the disintegration and decomposition of rocks, some explanatory remarks, in relation to them, are demanded at the outset of our investigations. The rocks of the globe consist of three prominent classes: PRIMARY, VOLCANIC, and SECONDARY. These terms are not used in their strictly geological sense. The Primary rocks are those which do not contain any vegetable or animal remains, and are supposed to have been formed before the creation of any living things upon the earth. For convenience of description, they are subdivided into the following orders: GRANITE, GNEISS, SYENITE, MICA SLATE, HORNBLLENDE SLATE, TALCOSE SLATE, CHLORITE SLATE, and ARGILLACEOUS SLATE, with some additional varieties. The first three orders, however, constitute the great bulk of the earth's crust, and must be noticed particularly, because of the connection that exists between the chemical elements of the minerals of which they are composed, and the inorganic elements of plants. The *mineral* characteristics of these rocks may be readily understood by the following statement of their composition. The *elements* of each one of the minerals may be learned from Table No. I, at the close of the volume.

GRANITE	is composed of	{	Feldspar, Quartz, Mica.	}	Unstratified.
GNEISS	“ “	{	Feldspar, Quartz, Mica.	}	Stratified.
SYENITE	“ “	{	Feldspar, Quartz, Hornblende.	}	Unstratified.

MICA SLATE is mainly composed of Mica and Quartz, HORNBLLENDE SLATE of Hornblende and Quartz, TALCOSE SLATE of Talc and Silica or Quartz, CHLORITE SLATE of Chlorite and Silica or Quartz, and ARGILLACEOUS SLATE of Alumina and Silica or Quartz.

A large number of other minerals, including the precious stones, are found intermingled in these formations, but they are of so little consequence, as to bulk, that they exert no appreciable influence, and are not taken into account by the chemist, in his investigations of the origin of soils. QUARTZ, FELDSPAR, MICA, and HORNBLLENDE, are, then, the principal minerals in the Primary rocks. Each one of these minerals, excepting Quartz, exists in several varieties, depending, mostly, upon the kind of *alkali* that enters into its composition. The three principal varieties of these minerals, Feldspar, Mica, and Hornblende, are given in Table No. I, where their chemical elements are stated. When TALC and CHLORITE, which have a much less extensive range, are added to these four, we have but six minerals as the chief constituents of the Primary rocks. STEATITE, or SOAPSTONE, and SERPENTINE, are rocks limited in extent, and closely allied, it will be noticed, to Talc and Chlorite.

The VOLCANIC ROCKS constitute an order that has been protruded through the other formations, by volcanic action. BASALT, TRAP, GREENSTONE, and LAVA, are the principal rocks in this order. Their mineral constituents are nearly identical with those of the Primary rocks—the three varieties of Hornblende and Feldspar named in Table No. I, forming the greater part of their bulk. They also include a class of minerals and precious stones, like the other formations, but so limited in extent as not to affect the soils.

The SECONDARY ROCKS are also composed of elements identical with those of the Primary; and are, therefore, supposed to have been derived from the disintegration and decomposition of the older formations. They are regularly stratified, and often abound in the petrified remains of vegetables and animals; many of which are similar to those now existing in the sea, and others of them bearing indications of having been drifted in from the land. For this reason, it

is believed that the Secondary Rocks, excepting a few limited deposits in the beds of fresh water lakes, have been formed in the ancient oceans, from the sedimentary matter carried in from the lands, by the agency of rains, rivers, tides, and ocean currents.

SOILS have no elements in their composition, with the exception of a portion of decomposing vegetable and animal substances usually intermingled in them, but such as are found in the rocks of the several geological formations, and are, therefore, supposed to be derived wholly from the decomposition and disintegration of rocks.

In localities where the soils have been formed from rocks *in place*, it will be an easy task to determine their chemical qualities, when those of the rocks themselves are known; but where the soils are composed of transported materials, as is the case over large areas of nearly all the continents of the globe, they will be found to vary greatly in different situations, and even on the same farm or field: hence the importance of a knowledge of the principles of Agricultural Chemistry, to those who are employed in the cultivation of the earth.

With these explanations, in reference to the origin of soils, &c., we shall proceed, in the next chapter, to notice the relations of the earth and atmosphere to the *vegetable kingdom*, and then commence the description of the elementary bodies which enter into the composition of *organic* and *inorganic* substances. The relation and dependence of the *animal kingdom* upon that of the vegetable, and upon the atmosphere, will be considered in the close of the volume.

CHAPTER II.

ORGANIC AND INORGANIC ELEMENTS:—OXYOEN—HYDROOEN—NITROGEN—AMMONIA—
CHLORINE—CYANOGEN—CARBON—CARBONIC ACID—SULPHUR—SULPHURIC ACID—
PHOSPHORUS—SILICA—ROBON.

THE *elements* entering into the composition of vegetable matter, are of two kinds—*organic* and *inorganic*. The former class of elements, comprising by far the larger portion of the bulk of vegetable bodies, consists of those parts which, during combustion, disappear in the state of gases, and the latter, of those that remain in the form of ashes. Combustion, therefore, in effect, is merely a separation of the organic from the inorganic elements of the substance which is burned. The same may be said, also, of the process of *digestion*. Vegetables, eaten as food by animals, undergo a process, in digestion, similar in its effects with that which takes place in their combustion: a separation of the organic and inorganic parts being effected, by which the former are converted into flesh and blood, while the latter pass off as excrement.

The process of decay, or *decomposition*, which dead trees and plants undergo, produces the same results as those of combustion and digestion: it being only a much slower one, and requiring years to accomplish that which, in the other cases, is done in an hour or a day.

By careful analysis, chemists have also discovered that the *ashes* of plants, left by burning, do not contain a single *inorganic element* that did not belong to the soils in which they grew; and repeated experiments have demonstrated, that a plant will not come to perfection in soils lacking any one of the elements found in the ashes of the mature plant of the same kind or species, except that one of the *alkalis* is sometimes substituted for another. It is inferred from this, that all the *inorganic* parts of vegetables are derived from the soils: that is to say, all that portion of vegetable matter which remains in the *ashes* after combustion, is taken up from the earth during the period of the growth of vegetables.

An examination of the Tables, at the close of the volume, will show how fully the chemical constituents of the ashes of vegetables correspond with those of the soils, and these, again, with those of the rocks from which the soils have been derived. Such an investigation will enable the reader to see, very clearly, the relations existing between the *earth* and the *vegetable kingdom*. A comparison of the organic elements of vegetables, (Table VII,) with the elements of the atmosphere, (Table VI,) will also show that, with a single exception, they are all derived from the atmosphere. The relation, then, that the earth and atmosphere bear to the vegetable kingdom, is this: the earth supplies to all vegetables the *inorganic* elements of their growth, while the atmosphere affords to them their *organic* elements.

In proceeding to describe the chemical elements to which reference has been made, the *gases* claim the precedence, as occupying the most important position; and these being disposed of, the remaining part of the chapter will embrace a notice of the *non-metallic* elements, existing as solids at the common temperature.

OXYGEN is a permanent gas, when uncombined, and is the most extensively diffused element in nature. It forms more than one-fifth part of the atmosphere, and nearly eight-ninths, by weight, of the waters of the globe; enters as a constituent into nearly all the earths and rocks, and, with a few exceptions, into all organic products. *Oxygen gas* is prepared by disengaging it from some substance with which it has entered into combination. By means of the galvanic battery, it may be obtained in large quantities from water, and, by the action of heat, from the oxyd of mercury, oxyd of manganese, or chlorate of potash. Oxygen may be made to unite with all the other elements except *fluorine*, and forms what are called *oxyds*, of which the rust of iron is an example. With the same element oxygen often unites in several proportions, forming a series of oxyds, which are distinguished from each other by the different prefixes enumerated in chemical nomenclature. Many of its compounds are *acids*, particularly those which contain more than one equivalent of oxygen to one of the other element, and com-

pounds of this nature are those which it most readily forms with the *non-metallic* elements: such as *carbonic acid* with carbon, *sulphuric acid* with sulphur, and *phosphoric acid* with phosphorus. But oxygen unites in preference with single equivalents of a large proportion of the *metallic* class of elements, and forms bodies which are called *bases*: such as *potash* with potassium, *soda* with sodium, *lime* with calcium, *magnesia* with magnesium, and *protoxyd of iron* with iron, &c. A certain number of its compounds are neither *acid* nor *alkaline*, and are therefore called *neutral bodies*: such as the *oxyd of hydrogen*, or water, &c. The presence of oxygen is essential to the support of *respiration* in animals, to the *combustion* of vegetable or animal substances, and to the *growth* of plants.

“The combinations of oxygen, like those of all other bodies, are attended with the evolution of *heat*. This result, which is often overlooked in other combinations, in which the proportions of the bodies uniting, and the properties of their compound, receive most attention, assumes an unusual degree of importance in the combinations of oxygen. The economical applications of the light and heat evolved in these combinations, are of the highest consequence and value, and oxidation alone, of all chemical actions, is practiced, not for the value of the products which it affords, and, indeed, without reference to them, but for the sake of the incidental phenomena attending it. Of the chemical combinations, too, which we habitually witness, those of oxygen are infinitely the most frequent, which arises from its constant presence and interference as a constituent of the atmosphere. Hence, when a body combines with oxygen, it is said to be *burned*; and instead of undergoing oxidation, it is said to suffer *combustion*; and a body which can combine with oxygen and emit heat, is termed *combustible*. Oxygen, in which the body burns, is then said to support combustion, and called a *supporter* of combustion.”* But every case of combustion, however familiar to us, is only a process of *oxidation*, in which the oxygen of the air com-

* Graham.

bines with the particles of the burning material. This is as true of the rapid burning of wood as it is of the rusting of iron. Both are the results of the combination of oxygen with these substances. But the oxidation of iron proceeds so slowly, that the heat evolved is dissipated as fast as produced, and never accumulates, while the more rapid oxidation of wood evolves heat in abundance. The oxidation of iron, however, can be made to progress with such rapidity as to produce a sensible evolution of heat, by introducing an iron rod, at a red heat, into oxygen gas. But iron is not the only substance that has its power of combining with oxygen increased by an increase of temperature. The affinity which all ordinary combustibles have for oxygen, is greatly promoted by heating them, and is rarely developed at all, except at a high temperature. For this reason, to insure the commencement of combustion, it is commonly necessary that the combustible be heated to a certain point. But the degree of heat necessary to inflame the combustible is, in general, greatly inferior to what is evolved during the progress of the combustion; so that a combustible, once inflamed, maintains itself sufficiently hot to continue burning until it is entirely consumed. Here the difference may be observed between combustion and simple *ignition*. A brick heated in a furnace till it is red hot, and taken out, exhibits ignition, but has no means within itself of sustaining a high temperature, and soon loses the heat which it had acquired in the fire, and, on cooling, is found unchanged. *Combustion* does not take place, as the brick includes no combustible matter to support it.

The oxidable or combustible constituents of wood, coal, oils, tallow, wax, and all ordinary combustibles, are the same, namely: *carbon* and *hydrogen*, which, in combining with oxygen, at a high temperature, always produce carbonic acid and water; the volatile bodies which disappear, forming part of the smoky column that rises from the burning body. In combustion, no loss whatever of ponderable matter occurs; nothing is annihilated. The matter formed may always be collected without difficulty, and is found to have exactly the weight of the oxygen and combustible together, which have disappeared.

The discovery that heat is evolved in the combination of chemical elements with each other, serves to explain the principle upon which the consumption of food by animals tends to keep up the heat of their bodies. The degree of heat evolved, depending upon the rapidity with which combustion proceeds, and the rapidity of combustion upon the degree of temperature at which the combustible comes into contact with oxygen, it follows that the heat evolved in the *combustion, digestion, and decomposition* of vegetable or animal substances, must be very different in degree in these several cases. The evolution of heat during decomposition, with a few exceptions, is generally imperceptible to the senses.

HYDROGEN. — This gas does not exist, uncombined, in nature; at least the atmosphere does not contain any appreciable proportion of hydrogen. But it is one of the elements of water, and thus enters into nearly every organic substance. This gas is obtained pure by decomposing water, or some other substance with which hydrogen has combined. The Tables exhibit hydrogen as everywhere present, in all animal and vegetable substances, and in some minerals. It is indispensable to the vegetable and animal kingdoms. It is eminently combustible, and burns when kindled in the air, with a yellow flame of little intensity, which moistens a dry glass jar held over it; the gas combining with the oxygen of the air in burning, and producing water.

NITROGEN, besides constituting a portion of the air, enters into the composition of most animal, and many vegetable substances. This gas is usually procured by allowing a combustible body to combine with the oxygen of a certain quantity of air confined in a vessel, by which process the nitrogen is left free. It is a singularly inert substance, and does not unite directly with any other single element, under the influence of light or of a high temperature, unless, perhaps with oxygen and carbon. To combine it with another body, requires the adoption of a circuitous method. A burning taper is instantly extinguished in this gas, and an animal soon dies in it, not because the gas is injurious, but from the privation of oxygen, which is required in the respi-

ration of animals. Nitrogen appears to be chiefly useful in the atmosphere as a diluent of the oxygen, thereby repressing, to a certain degree, the activity of combustion and other oxidating processes. By reference to the Tables of organic analyses, it will be seen that nitrogen is a constituent of the nutritious articles of food, both animal and vegetable.

AMMONIA.—This gas is a compound of hydrogen and nitrogen, in the proportion of *one* atom of nitrogen to *three* of hydrogen. It is produced in the *destructive distillation* of all organic matters containing nitrogen, which has given rise to one of its popular names—the spirits of hartshorn: there being a large per cent. of nitrogen in deer's horns. It is also produced during the *putrefaction* of the same matters, and finds its way into the atmosphere.

Ammonia is a colorless gas, of a strong and pungent odor. It is inflammable in air in a low degree, burning in contact with the flame of a taper. Water is capable of dissolving about 500 times its volume of ammoniacal gas in the cold, and the solution is always specifically lighter, and has a lower boiling point than pure water. Ammonia, in solution, is decomposed by chlorine. It is distinguished as the *volatile alkali*, as it restores the blue color of litmus paper reddened by an acid, and exhibits, in other respects, the properties of an alkali. Ammonia forms several classes of compounds with acids and salts, and exhibits highly curious reactions with many other substances. It will be seen, as we proceed, that it is a highly important agent in agriculture.

CHLORINE.—This is one of the simple gaseous elements, is of a pale yellowish green color, has a peculiarly suffocating odor, is capable of being condensed into a limpid liquid of a bright yellow color, has not been consolidated by freezing, and is easily combined with water. It exists abundantly in sea-water, and combines with sodium to form *common salt*. It destroys all vegetable and animal coloring matters, and hence is invaluable for bleaching linens and muslins. In combination with lime, it acts as a powerful disinfecting agent, in freeing the atmosphere of hospitals, close rooms, and cellars, from impurities generated by the decomposition of vegetable and animal substances. It combines with all

the metals, and in the same proportions as oxygen; and, with three or four exceptions, these compounds are soluble and sapid.* It is also absorbed by alkaline solutions. It does not, under any circumstances, unite directly with oxygen, although several compounds of these elements can be formed; nor is it known to combine directly with nitrogen or carbon. It is "the leading member of a well marked natural family, to which also bromine, iodine, and fluorine belong. Phosphorus, carbon, hydrogen, sulphur, and most of the bodies of this class, have little or no action upon each other, or upon the mass of hydrogenous, carbonaceous, and metallic bodies to which they are exposed in the material world; all these substances being too similar in nature to have much affinity for each other. But the class to which chlorine belongs ranks apart, and, with a mutual indifference for each other, they exhibit an intense affinity for the members of the other great and prevailing class—an affinity so general as to give the chlorine family the character of extraordinary chemical activity, and to preclude the possibility of any member of the class existing in a free and uncombined state in nature. The compounds, again, of the chlorine class, with the exception of those of fluorine, are remarkable for solubility, and, consequently, find a place among the saline constituents of sea-water, and are of comparatively rare occurrence in the mineral kingdom; with the single exception of *chloride of sodium*, (common salt,) which, besides being present in large quantities in sea-water, forms extensive beds of *rock salt* in certain geological formations."†

Although chlorine, as has been stated, does not combine directly with oxygen, nitrogen, or carbon, and may be mixed with hydrogen and preserved in the dark without uniting, yet a combination of these two elements is produced, with explosion, by the introduction of spongy platinum, or the electric spark, or by exposure to the direct rays of the sun. Even under the diffuse light of day, combination of these two gases takes place rapidly, but without explosion. Chlorine has such a strong affinity for hydrogen, as to decompose

* Having a taste.

† Graham's Elements of Chemistry, p. 329.

most bodies containing that element, and in this process *hydrochloric acid* is always formed. This is the *muriatic acid* of commerce. The affinity of chlorine for most metals is equally great: antimony, arsenic, and several others, showered in powder into this gas, take fire, and produce a brilliant combustion.

Chlorine, in some of its combinations, exists in all productive soils, and, from its active properties, in producing chemical changes upon nearly all animal, vegetable, and mineral substances, it is a most important agent in agriculture.

CYANOGEN.—This gas, though a compound of carbon and nitrogen, unites with other elements exactly in the same manner as though it were itself an element, and forms an exception to the rule, that simple bodies can only combine with simple, and compound only with compound bodies. It comports towards other bodies in a manner similar to that of chlorine, iodine, and fluorine. With iron it forms *prussian blue*, and with hydrogen the *prussic acid*. Under pressure this gas is condensed into a limpid liquid, which evaporates again on removal of the pressure. Cyanogen is a *salt-radical*, and unites with all the metals as chlorine and iodine do, forming a class of *cyanides*. It may be obtained pure from the cyanide of mercury.

FLUORINE.—This substance has not hitherto been isolated, by the utmost skill of the chemist, as its powers of combination are such that no simple body has been found capable of resisting its action. It is found as a component of a few mineral substances only; one of these, *fluor spar*, is very abundant, and is noticed under the head of LIME and its compounds.

This closes our notice of the simple gaseous bodies. Those named hereafter are formed by the union of one of these gases with some one of the solid elements.

CARBON is found in great abundance in the mineral kingdom, united with other substances, as in coal, of which it is the basis, and in the acid of carbonates. It is also the most abundant element of the solid parts of both animals and vegetables. It exists in nature, or may be obtained by art, under a variety of appearances, possessed of very different

physical properties. It occurs crystallized in the *diamond* and *graphite*, or *black lead*, uncrystallized in *wood charcoal*, *anthracite coal*, &c. Carbon may be said to surpass all other bodies whatever, in its affinity for oxygen at a high temperature; and being infusible, easily got rid of by combustion, and forming compounds with oxygen which escape as a gas, this body is more suitable than any other substance to effect the reduction of metallic oxyds: that is, to deprive them of their oxygen, and to produce from them the metal, with the properties which characterize it. When heated to low redness, it burns readily in air or oxygen, forming *carbonic acid* by its union with oxygen. The prominent position which carbon occupies in the composition of vegetable and animal substances, may be seen in the Tables.

CARBONIC ACID.—This gas is formed by the union of oxygen and carbon, in the proportion of *one* equivalent of carbon to *two* of oxygen. It is easily prepared from fragments of marble, limestone, or chalk, by pouring upon them sulphuric acid, or muriatic acid. It is thrown off from the lungs of all air-breathing animals. It is also a product of vinous fermentation, and is largely produced in the burning of wood or coal. It is discharged from the earth by active volcanoes, and from fissures in their neighborhood, long after they are extinct. It is evolved in the decomposition of animal and vegetable matter, and accumulates in vaults and wells as the *choke-damp*, occasionally so fatal to those who descend incautiously into such places. Although enormous quantities of carbon are constantly abstracted from the atmosphere, in the growth of plants, yet the supplies from the above named sources, and a few others, seem amply sufficient to prevent any sensible diminution of its carbonic acid. It would seem that the decomposition of the vegetation of one period supplies the necessary elements for the productions of the succeeding one, and that thus the amount of carbon in the atmosphere, is kept constantly equalized.

SULPHUR is distributed very generally throughout the earth by means of its combinations with minerals and metals, which, in their decomposition, supply this element to the soils. It is furnished abundantly from many volcanoes no

longer in a state of much activity, where it is collected for the supply of commerce. It is supposed to be the strongest chemical body, next to oxygen, and has, like it, a powerful affinity for all other elements. Sulphur, or its acids, unites with iron, lead, copper, zinc, lithia; with oxygen, hydrogen, nitrogen, carbon, phosphorus, ammonia; with silicon, alumina, potash, soda, lime, magnesia, manganese; with fibrin, gluten, starch, albumen, blood, cartilage, &c. Its other combinations, which are numerous, have little connection with agriculture, and need not be noticed. Sulphur burns readily at a very moderate heat, and is used in connection with phosphorus in the manufacture of friction matches. Possessing such active properties, sulphur is ever ready to perform its offices in the vegetable and animal kingdoms. SULPHURIC ACID, one of its most powerful products, in combination with oxygen, consists of *one* equivalent of sulphur and *three* of oxygen.

PHOSPHORUS is essential to the organization of the higher orders of animals, being found in their fluids, and forming, in combination with lime, the basis of the solid structure of their bones. It is also found in most plants and minerals. Phosphorus, in its properties, is very closely allied to sulphur, but melts, boils, burns, and evaporates far more easily than that element. So readily does the oxygen of the atmosphere act upon it, and produce combustion, that it must be kept, and also cut, under water, especially when the atmosphere is at the temperature of summer heat. It is on this account that it is so valuable in the composition of friction matches, the temperature being sufficiently raised by a very little friction, to ignite it. It is soluble in ether, alcohol, sulphuret of carbon, and oils. It is an exceedingly violent poison, and is used to extirpate rats and mice. Phosphorus is susceptible of four different degrees of oxidation—the highest of which is a powerful acid, and the acid character is not absent even in the lowest. Phosphorus, or its acids, has the power of combining with hydrogen, oxygen, nitrogen, chlorine, sulphur, ammonia, alumina, potash, soda, magnesia, lime, iron, manganese, lithia, and a large range of other elements, not connected with the growth of vegeta-

tion. With such extensive affinities, phosphorus must be an important element in soils. PHOSPHORIC ACID, which is so often named in the Tables, consists of *one* equivalent of phosphorus and *five* of oxygen.

SILICA, SILEX, or QUARTZ, which occurs so abundantly in the inorganic parts of vegetables, is a compound of oxygen and SILICON, in the proportion of about *one* part of the latter to *three* of the former. It constitutes a number of minerals, nearly in a state of purity; such as common quartz, rock crystal, flints, sandstone, chalcedony, carnelian, agate, opal, common sand, and the water-worn, white pebbles met with almost everywhere. It also enters largely into combination with other substances, to form the rocks of the globe.* It exists in two states in soils, *soluble* and *insoluble*. In its soluble state, it is taken up by plants during their growth, and constitutes a part of their mass, entering largely into the composition of the stalks of reeds and grasses, which have often a thick crust of silica on their bark. It is a very abundant mineral, and is estimated to constitute one-sixth of the crust of the globe.

But it is not in the bark of plants alone, that silica is met with by the chemist. It is diffused generally throughout the structures in which it occurs, says QUEKETT,† the latest writer on the subject, and in this connection is so intimate and equable, that it forms a complete skeleton of the tissues after the soft vegetable matters have been destroyed; in fact the part it plays in reference to the organized tissues in which it is deposited, is precisely analogous to that existing between the animal and earthy elements of shell. Silica exists in such great abundance in the cuticle of a plant known as *equisetum hyemale*, or Dutch rush, that on this account the stems are employed by carvers in wood and modelers in clay, as a substitute for sand paper. It is also very abundant in the canes, but is by no means limited to this order of plants. It is contained principally in the cuticle, or outer bark, and in the various structures that are developed from it, such as hairs, spines, &c.; but in some instances layers

* See Table I.

† London, 1852.

of cells lying much deeper than those of the cuticle, also abound in silica; and it may also be met with in woody fibres and in spiral vessels. In the burning of a haystack, masses of perfectly formed glass are always to be found among the ashes. This glass is produced by the combination of the silica of the cuticle of the hay with the potash of the woody fibre—glass being a silicate of potash.

In order to display effectually the siliceous matter in plants, it is necessary to expose the tissue under examination, to the flame of the blow-pipe, or, better still, to boil it for some days in nitric acid. By these means, the organic portion is entirely destroyed, and the silica, withstanding these destructive agents, remains as a perfect model, or cast of the original tissue. In the husk of a grain of wheat, not only the cells of the cuticle, and layers of cells beneath, but also the fibres of the spiral vessels are silicified. Of all the grasses or grains used as food by man, rice contains the largest proportion of silica. In the husk of the rice, the woody fibres are also coated with silica; and in wheat, oats, and other grains, not only the stalks, but the hairs which stud the surface of their husk, partake largely of the siliceous deposit.

It will now be apparent that a vast amount of *silica* is yearly removed from our soils by the cultivation of the ordinary grains and grasses, and that a supply of this substance may be necessary to many soils, in order to insure good crops.

BORON is an element sparingly diffused in nature, and having some analogy to carbon. It is never found except in combination with oxygen as BORACIC ACID. It is a constituent of several minerals, but the main supply of borax to commerce is from certain hot lagoons in Tuscany, and likewise from the hot springs of Lipari, and a few other places. It communicates fusibility to many substances in uniting with them, and generally forms a glass. On this account borax is much used as a flux. With the assistance of the vapor of water, it is slightly volatile, but alone it is more fixed, and fuses, under a red heat, into a transparent glass. Boracic acid is remarkable for the variety of proportions in which it unites with the alkalies.

All the foregoing elements are *non-metallic*. A brief review of their peculiar properties will close our remarks upon them.

Oxygen, hydrogen, nitrogen, and carbon, form the chief elements of plants and animals, and are, for this reason, called *organogens*, or generators of organic bodies.

Sulphur and phosphorus, with some of their compounds, are characterized by such great inflammability, that they have been called *pyrogens*, or fire generators.

Chlorine, iodine, bromine, fluorine, and cyanogen, on account of their power of producing *salts* in combination with the *metals*, have been called *halogens*, or salt producers. Their compounds are called *haloid salts*, to distinguish them from the *oxygen salts*, which consist of an acid and a base.

Silicon and boron occur in nature only in combination with oxygen, as silica and boracic acid. These substances are oxyds, and form amorphous salts with many bases, such as glass, slag, glazing, &c., and for this reason they have been called *hyalogens*, or glass producers.

CHAPTER III.

INORGANIC ELEMENTS: — POTASH — SODA — LITHIA — LIME — MAGNESIA — BARYTA —
STRONTIA — ALUMINA — IRON — MANGANESE.

HAVING disposed of the gases and non-metallic elements, the *light metals* may be next considered. They are called light metals, because they are specifically lighter than other metals. These metals, so far as they are connected with agriculture, may be noticed in the following order :

1. Potassium, sodium, and lithium, the metallic bases of the *alkalies*.

2. Calcium, magnesium, barium, and strontium, the metallic bases of the *alkaline earths*.

3. Aluminium, and several kindred but rare metals, the metallic bases of the *earths*.

All these metals have such a strong affinity for oxygen, that they are usually met with only as oxyds, and it is to their properties in this form, that attention will be directed. The processes by which the pure metals are obtained, can be learned from the common chemical works.

POTASH, or POTASSA, is an *alkali*, formed from its metallic base, *potassium*, by the chemical union of oxygen with this metal. This element is capable of forming several compounds with oxygen, and also enters into chemical combination, in various proportions, either as potassium or potash, with sulphur, chlorine, iodine, iron, cyanogen, carbon, hydrogen, nitrogen, silica, acetic acid, tartaric acid, oxalic acid, &c. The extent of its presence in minerals and vegetables, can be learned from the Tables. Its capacity for combining with so many of the elements existing in soils, and its almost constant presence in plants and trees, render it indispensable to the growth of vegetables.

SODA is an alkali, formed from its metallic base, *sodium*, by the chemical union of oxygen with this metal. Soda and sodium are capable of forming compounds with sulphur, chlorine, carbon, nitrogen, phosphorus, iodine, silica, boracic

acid, &c. Like potash, it is of much importance in soils, as it enters largely into the composition of certain vegetables. In combination with chlorine, it forms *common salt*, which is the chloride of sodium, and with sulphur it produces the *glauber salts*, or sulphate of soda. "As potassium is in some degree characteristic of the vegetable kingdom, so sodium is the alkaline metal of the animal kingdom, its salts being found in all animal fluids."*

LITHIA, which is an oxyd of *lithium*, is not an abundant element. It exists in small quantities in a few minerals, and is met with in a few vegetables. It is a constituent of unhealthy urine, where it occurs as *lithic acid*. Lithia and lithium enter into combination with chlorine, hydrogen, carbon, sulphur, soda, phosphorus, fluorine, &c. It is an *alkali*, like potash and soda.

LIME is an *alkaline earth*, having *calcium* for its base, and is formed by the chemical union of oxygen with that metal. Lime and calcium form chemical combinations with carbon, sulphur, chlorine, phosphorus, nitrogen, hydrogen, fluoric acid, &c. Uncombined lime, or quick lime, which is the pure *oxyd of calcium*, can be obtained by heating common limestone to redness. This rock is a *carbonate of lime*, consisting of 43.71 parts of carbonic acid and 56.29 of lime, in 100 parts. Marble, calcareous spar, chalk, marl, coral, the shells of molluscous animals, &c., are all carbonates of lime, more or less pure. In burning any of the marbles or limestones, the heat drives off the carbonic acid, and leaves the pure oxyd of calcium, or common lime.

Lime, in combination with sulphur, forms *sulphate of lime*, or *gypsum*, which is composed of sulphuric acid 46.31 parts, lime 32.90, and water 20.79, in 100 parts. Heated to a proper temperature, the water is driven off, and *plaster of Paris* produced. Gypsum possesses highly beneficial properties as a fertilizer of soils. *Phosphate of lime* is composed of phosphoric acid 48.45 parts and lime 51.55, in 100 parts. This mineral enters largely into the composition of the bones of animals. The *fluuate of lime*, or *fluor spar*,

* Graham.

is composed of fluorine 47.73 parts and lime 52.27, in 100 parts. This mineral forms a very small portion of the earth of bones, but a somewhat larger proportion of the enamel of teeth. The *chloride of lime* has been noticed under the head of chlorine. Lime, in its various combinations in soils, performs the most important offices to vegetation, while at the same time it supplies a portion of the materials of the growth of plants.

MAGNESIA is an alkaline earth, having *magnesium* for its base, and is formed by the chemical union of oxygen with that metal. Magnesium has the color and lustre of silver. It is very ductile, and capable of being beaten into thin leaves, fuses at a gentle heat, and crystallizes in octahedrons. It undergoes no change in dry air or oxygen, but is oxydized superficially by moist air. Magnesium, when heated to redness, burns with great brilliancy, forming magnesia, or the oxyd of magnesium. Magnesia is extensively diffused in the mineral kingdom, forming a large per cent. of the chloritic, talcose, and serpentine rocks, and is also a constituent of hornblende and one variety of mica.* Carbonate of magnesia occurs native as a hard, compact mineral, in the proportion of magnesia 48 parts, carbonic acid 49, and water 3, in 100 parts. Magnesia is also extensively diffused in combination with lime, as a rock, called, *dolomite* or *magnesian limestone*, which is composed of carbonate of lime 54.18 parts and carbonate of magnesia 45.82 parts, in 100. Magnesia, or its base, combines with silica, boron, carbon, hydrogen, chlorine, sulphur, phosphorus, nitric acid, and ammonia. The extent of the diffusion of magnesia in the vegetable kingdom, can be learned from the Tables.

BARYTA and STRONTIA are also *alkaline earths*, and have a great similarity to lime in their properties and combinations, but need not be noticed in detail in a work on agricultural chemistry.

ALUMINA is an oxyd of *aluminum*, formed by the union of *three* parts of oxygen to *two* parts of this metal. It is the only one of the *earths proper* that occurs in abundance. It

* See Table No. I.

exists in its pure state, with the exception of a trace of coloring matter, in the *sapphire*, of which the oriental *ruby* and *topaz* are varieties. *Emery* is nearly pure alumina. All these substances are extremely hard, being, in that respect, second only to the diamond. Like silex, alumina is an abundant ingredient in many minerals and slaty rocks, and is the principal constituent in clays. In combination with sulphuric acid and potash, it forms *alum*, and may be obtained in its metallic state from this salt. Its great capability of absorbing water, renders it of vast importance in soils, as a means of supplying moisture to the roots of vegetables. Its affinity for vegetable and mineral *coloring matters*, and its power of retaining and rendering them insoluble, connected with its equally powerful affinity for *ligneous fibre*, makes alumina indispensable in the arts and in manufactures. It also absorbs carbonic acid and ammonia, and supplies these two elements to vegetables. In combination with silica, it supplies the clays for bricks, porcelain, earthen-ware, stone-ware, &c. Alumina, or its base, enters into combination with hydrogen, chlorine, iodine, bromine, fluorine, nitrogen, sulphur, potash, soda, lithia, magnesia, manganese, iron, selenium, phosphorus, cyanogen, borax, &c.

“Next to silica, alumina occurs most frequently in nature, and, indeed, not only in clay and loam, but also in rocks and minerals; for instance, the well known gray colored clay-slate, porphyry, &c. Feldspar must be regarded as the most important of the alumina minerals, and is found in greater or less quantity in granite, gneiss, mica slate, and other rocks. Feldspar, like other stones, is finally disintegrated by the influence of air and water, and by heat and cold; it weathers, as the miners say, or is dissolved, and the silicate of potassa is thereby gradually removed by the water, so that, as the result of this decomposition, clay or loam remains behind. When the farmer lets his plowed land lie *fallow*—that is, remain uncultivated for some time—he by this means accelerates the weathering; soluble salts of potassa, soda, lime, and other salts, are thereby formed from the constituents of the soil, and to these salts especially,

is to be attributed the greater fertility of fallow land over that which has been exhausted by cultivation."* The same process of decomposition takes place in the other minerals of the rocks composing the earth's crust, and by this means soils are produced. The proportions in which their several elements are supplied to soils, can be ascertained by reference to the Tables.

GLUCINUM, and the several other metallic bases of the *earths*, closely allied to aluminum, occur so very rarely as not to demand a notice.

This closes what is considered necessary to be said in explanation of the properties of the *light metals*, which constitute the bases of the *alkalies proper*, the *alkaline earths*, and the *earths proper*. A few remarks in relation to each of these classes, however, by way of retrospect, will be useful to the reader.

Of all bodies, the *alkali metals*, potassium and sodium, have the greatest affinity for oxygen; and their oxyds, potash and soda, are the most powerful *bases*,† with which other elements unite to form compounds. Ammonia is also classed with the alkalies. These three alkalies are easily soluble in water, exert a strong caustic action on animal and vegetable substances, and have a great affinity for carbonic acid, which they absorb eagerly from the atmosphere, thereby becoming converted into alkaline carbonates. The carbonic acid in combination with these alkalies, cannot be expelled by heating, but it escapes immediately, with effervescence, on the addition of other acids. These carbonates are also easily *soluble* in water, and have a basic reaction. Potash and soda, combined with sand at a high temperature, yield melted *glass*; and when dissolved in water and mixed with fat, on being boiled together, they yield *soap*. Most of the salts which the alkalies form with acids, are soluble in water, and thus the moisture in soils affords them the opportunity of performing their part in the chemical preparation of the food of plants.

* Stockhardt.

† In the language of chemistry, any alkaline or earthy substance, combining with an acid, forms a compound or salt, of which it is the *base*.

The metals of the *alkaline earths*, calcium, magnesium, &c., have also such a very strong affinity for oxygen, that the preparation of them is very difficult. The oxyds of these metals, lime, magnesia, &c., though alkaline, are called *alkaline earths*, because they are *sparingly soluble*, while the alkalies are *easily soluble*. They are also less caustic than the alkalies, and, like them, eagerly absorb carbonic acid from the air, and form *carbonates* which are solid, and *insoluble* in water, while the carbonates of the alkalies are *easily soluble*. The carbonates of the *alkaline earths*, on the other hand, lose their carbonic acid by exposure to a powerful heat, while the *alkalies* do not.

The *earths*, alumina, &c., unlike the *alkalies* and *alkaline earths*, are entirely *insoluble* in water, which they absorb largely, like a sponge. But alumina, it has generally been supposed, does not combine chemically with carbonic acid, but only absorbs it freely, as it does water, and retains both as agents to aid in the preparation of the other elements in the soil as food for plants. A part of the carbon of plants is now supposed to be derived from the soil, though their whole supply of this element had long been considered as derived from the atmosphere.

IRON and MANGANESE.—Of the *heavy metals*, these two only need be noticed, as they alone, of this class, enter into the composition of the common vegetables cultivated by the farmer.

The extent to which *iron* is appropriated in the growth of animals and vegetables, can be seen in the Tables. Being always present, in quantities larger and smaller, in the rocks, and entering into combination with many of the elements of the soils, the agriculturist need have little fear that his lands will become deficient in this element.

Iron combines with oxygen, carbon, chlorine, sulphur, phosphorus, cyanogen, potash, acetic acid, &c.

Manganese, in some of its forms of combination with oxygen or chlorine, enters sparingly into the composition of minerals and vegetables. It is never found as a metal in nature, but may be produced from its black oxyd by a high heat with charcoal.

CHAPTER IV.

PROXIMATE ELEMENTS:—STARCH—ALBUMEN—GLUTEN—CASEIN—LEGUMIN—EMULSINE—
PROTEIN—GELATIN—CHONDRIN.

THE *organic* and *inorganic* elements obtained from the earth and atmosphere, by vegetables and animals, during their growth, have now been sufficiently described, we trust, to enable the reader to gain a competent knowledge of their chief properties. We may, therefore, proceed to notice the *proximate constituents* of which the products of the vegetable and animal kingdoms are composed.

On turning to Table VII, which embraces the *organic* analyses of the grains, straws, and roots, used as food, and to Table VIII, which includes the muscular fibre, skin, tendons, fat, &c., of animals, it will be seen that they are all composed of nearly the same simple elements; the only difference being in the proportions that these elements have entered into combination in the several articles named. These vegetable and animal substances are the *ultimate products* of the action of vegetable and animal life upon the simple elements constituting the soils and atmosphere. It is unnecessary to make any other notice of these articles than that embraced in their chemical analyses.

But these *ultimate products* are capable of being subdivided into several distinct and very dissimilar substances or elements, called their *proximate elements* or *constituents*, which do not appear to the eye in their ordinary state. Take the common grains, and peas and beans as an example: they contain ten substances, besides the woody fibre of their husks, that differ from each other in the proportions or mode in which their elements are combined. These are starch, sugar, gluten, casein, fibrin, albumen, protein, legumin, hordein, and fatty matter. With two or three exceptions, the analyses of these articles are given in Table X. This Table also embraces the analyses of the corresponding *proximate constituents* obtained from the solid parts of animals.

The fibrin, albumen, casein, and protein, found in the *ultimate products* of vegetables and animals, are so nearly identical in their chemical composition, as to be considered the same elements in both kingdoms. The difference in the albumen from wheat, and from the serum of blood, for instance, is not greater than between the former and that from some one of the other grains. For this reason, it is considered that it is the province of plants to draw the elements of these compounds from Nature's great store-house, and to elaborate them into the forms in which they are yielded by them to the agriculturist and the chemist; while it only remains for the *graminivorous* animals to appropriate the aliments thus prepared, unchanged, into their systems, the process of digestion and assimilation being merely a provision of nature to separate these elements from their union with each other in the vegetable state, and to recombine them in the animal tissues. The office of vegetables, therefore, is to elaborate the elements of the atmosphere and soils, into suitable substances for the support of animal life. But as certain orders of animals can only subsist upon *flesh*, it would seem that the plant-eating animals, with their large stomachs, are designed to perform the task of concentrating the elements of vegetables into smaller compass, for the use of the *carnivorous* animals and of man.

The study of the Tables, it is thought, may tend to change the opinions of some who reject the use of animal diet as pernicious, seeing that it contains nothing but what is found in the very vegetables recommended as substitutes; the only difference being, that to secure an equal amount of nutriment from vegetables, requires the stomach to receive and digest a bulk five or ten times greater than is supplied by animal food. With these remarks, we shall proceed to notice the proximate elements of vegetable and animal substances named in the Tables.

STARCH.—This substance, so well known to every housewife, is deposited in most vegetables, particularly at the period of ripening, from the juices with which the cells of the plants are filled. To the naked eye it appears like particles of meal, but under a powerful microscope, it is found

to consist of small grains or globules. The form of these grains differs in different plants, those from wheat being flattened. The process of its separation from the other elements with which it is combined, is well understood. When obtained from potatoes, they are rasped on a grater, the pulp kneaded with water, and the liquid then squeezed out through a linen cloth. The *woody fibre* of the cells remains behind, but the juice, together with the starch, runs through, into the vessel prepared for its reception. The starch settles to the bottom, and is secured by pouring off the liquid. The process of obtaining starch from the common grains, varies but little from that adopted to extract it from potatoes, except that the grains are crushed by grinding, or softened by maceration in water, and mashed.

Starch does not dissolve in cold water, and only swells up on boiling. In this process the grains of the starch absorb water, and swell up, so that the single membranes which coat them, break open. The substance thus produced, is called *starch paste*, and is used in various ways for stiffening, or starching muslin and linen. When this paste is allowed to remain in a warm place for a length of time, it gradually becomes thin and sour. The peculiar acid thus formed, is called *lactic acid*, being the same with that produced in the souring of milk. Starch does not contain any nitrogen, and is not ranked among the elements of *nutrition*, but, like sugar, fat, &c., is supposed to be only an element of *respiration*. This point will be noticed more fully hereafter.

ALBUMEN.—The clear liquid decanted from the starch, when heated in a flask, becomes turbid as the fluid approaches the boiling point. After boiling for a few moments, it deposits a flaky grayish-white substance, which can be collected on a filter. This is *vegetable albumen*. It readily dissolves in cold and in warm water, but, like the albumen of the whites of eggs, and of the serum of blood, with which it is identical, it coagulates in boiling water. It contains nitrogen, and is classed with the elements of nutrition. It also contains a small per cent. of sulphur and phosphorus. It will be noticed that starch is destitute of these elements. By referring to the Tables of analyses, it will be found that

albumen has a very extensive range as a proximate element in the vegetable and animal kingdoms.

GLUTEN.—When wheat flour is mixed with water, so as to form a stiff paste, and enclosed in a piece of thick linen, all its starch, albumen, gum, and sugar, may be pressed out by kneading the mass, and occasionally adding more water, or by placing it beneath a spout of running water. The cloth will then contain *woody fibre* and a viscous, tough, gray substance, called *gluten*. In this crude state, when separated from the woody fibre, it has been called *vegetable fibrin*. It only swells up in water, without being completely dissolved. The *gluten* thus obtained, according to Brande, consists chiefly of four distinct substances, which may be separated from each other in the following manner: The crude gluten is boiled in alcohol, strong at first, and afterwards weaker; there remains a gray fibrous substance, which is the pure vegetable *fibrin*, and the alcoholic solution, as it cools, deposits *casein*. If, after this, the liquid be poured off and carefully evaporated, a pultaceous substance is obtained, which is *gluten* mixed with *fat*. To free it from the latter, it is dried, pulverized, and digested in anhydrous ether as long as it imparts anything to that solvent; the residue is then washed with alcohol, afterward with water, and ultimately dried, and thus the pure *gluten* is secured. It appears, therefore, that the crude, or original gluten, as obtained from the wheat flour, is a mixture of *fibrin*, *casein*, *gluten*, and *oily* or *fatty matter*. It is gluten that gives to wheat flour its peculiar tenacity when formed into dough. This element is exclusively a vegetable product, and does not occur in the animal kingdom. As far as the relative proportions of its ultimate elements are concerned, it is almost identical with albumen. It contains nitrogen, sulphur, and phosphorus, but the proportions of the two latter elements, entering into its composition, have not been determined. For the extent of its range in the common vegetables, see Tables.

FIBRIN.—This element, like albumen, is common to both vegetable and animal substances. The process of its separation from wheat flour, is given under the head of gluten.

To obtain fibrin from animal substances, is not a difficult process. Fresh drawn blood, when left in a vessel to cool, separates into two parts: the one a red jelly, or *coagulum*, and the other a yellowish liquid, or *serum*. When the *coagulum* is long agitated in water, the coloring matter of the blood is washed out, and a soft white fibrous mass remains. This is *animal fibrin*. When the *serum* of blood is heated to boiling, it coagulates to a white jelly; because it consists of a solution of *animal albumen*. Fibrin may also be obtained by agitating blood as it flows from the vessels, with a rod, to the twigs of which it adheres in the form of fibrous filaments, which may be cleansed of coloring and other soluble matters, by repeated washings in fresh portions of water. Fibrin may also be obtained from muscle. In its humid state, fibrin retains about 75 per cent. of water, and requires to be further purified, to free it from fatty matters. Dry fibrin absorbs about thrice its weight of water, when immersed in that fluid, and regains much of its original appearance before having been dried. "It is insoluble in cold and in hot water, but when subjected to protracted boiling, it shrinks, and becomes friable, traces of ammonia are evolved, and a liquor is obtained which, when filtered and evaporated, leaves a brittle yellowish substance, having the smell of boiled meat, and soluble in water; it does not gelatinize, but it yields a peculiar flocculent precipitate with infusion of galls. The residuary portion of the fibrin has lost the original properties of that substance, and has acquired those of coagulated albumen. DUMAS observes, that this experiment establishes a well-marked line of demarcation between *fibrin* and *albumen*, or *casein*, which two last substances do not yield these products of fibrin."* Fibrin is not altered by heat, till it begins to decompose; it then fuses, swells up, and burns with a yellow sooty flame, leaving a porous and brilliant charcoal, that is difficult to burn to ashes. The ash amounts to near one per cent. of the dry fibrin, and consists chiefly of phosphate of lime, a little phosphate of magnesia, and traces of silica. It contains nitrogen, and is preëminently an element of nutrition.

* Brande.

CASEIN.—This term has been chiefly applied to the peculiar coagulable principle of milk. A similar substance is occasionally found in the blood, in the pancreatic juice of the ox and sheep, and in some vegetables. Though our Tables of the *proximate* analyses of the grains and fruits, with a few exceptions, include no casein, yet many of them embrace it in their composition. It can be obtained pure from the curd of milk, by separating it from the butter which is combined with it. *Vegetable casein* was obtained from the crude gluten of wheat, by Dumas and Cahours, by boiling it in weak alcohol, as noticed above. They found its properties to correspond with those of the casein of milk.

For obtaining *casein* from peas, STOCKHARDT directs that, after the starch and albumen have been extracted, as in the case of wheat flour, before mentioned, a few drops of some acid be added to the remaining liquid. This process at once precipitates the *casein*. Vegetable casein, like vegetable albumen, gluten, and fibrin, contains nitrogen; but it is distinguished from albumen by its not being *coagulated* by boiling, though it is by acids. Its coagulability by *runnet*, as in the process of curd and cheese making, is also one of its distinctive characteristics. It contains sulphur, but no phosphorus, not at least in the peculiar state of combination in which these two substances are found in albumen and fibrin. It is, however, intimately combined with a certain proportion of phosphate of lime. Casein ranks with the elements of nutrition. It is very abundant in peas, beans, lentils, &c.

LEGUMIN is the nitrogenized principle of peas, beans, and many similar seeds. It is considered by LIEBIG and WÖHLER as identical with casein, and by DUMAS and CAHOURS as the same with emulsine. It may be obtained by steeping ground peas in warm water for a few hours, so as to soften them, and then macerating them in cold water for an hour, and pressing out the liquor, which is left to deposit its suspended starch, and filtered. Dilute acetic acid is then carefully dropped into the liquid so as to precipitate the legumin. It falls in the form of white flakes, and may be dried and freed from fatty matters by the same process used

for gluten. Legumin differs from the other nitrogenized elements in several particulars. It is a very nutritious element.

EMULSINE.—This element, which closely resembles legumin, is contained in certain oil-producing seeds and kernels, but especially in *almonds*, from which it is most easily obtained, by a process similar to that pursued in the production of legumin. DUMAS and CAHOURS, as already stated, consider emulsine and legumin as identical, and the result of their ultimate analysis seems to justify such a conclusion; so also legumin and casein are regarded, by LIEBIG, as one and the same principle. It will be seen, however, in the notice of protein, that, as far as concerns the quantitative proportions of the carbon, hydrogen, oxygen, and nitrogen contained in the substances now under consideration, they may all be regarded as derived from one radical, yet there are peculiarities belonging to each sufficient to characterize them as distinct, or perhaps *isomeric** proximate principles.†

PROTEIN.—“Although, as has been remarked, [in relation to albumen, gluten, fibrin, casein, legumin, and emulsine,] there are certain distinctive peculiarities apparently belonging to each of the preceding substances, sufficient to establish them as separate *proximate principles*, yet the general resemblances which pervade them, long ago induced chemists to regard them as of common origin, and as deriving their peculiarities from small quantities of superadded substances, especially sulphur, phosphorus, and certain salts, rather than from any original and essential difference of quantitative ultimate composition. These views have been amply sanctioned by the discovery of the identity of the above compounds as derived from animals and vegetables, and more especially by the researches of MULDER, establishing the existence in all of them of a common base, which appears to derive its origin from the vital powers of plants, and to be transmitted from them to animals, as an essential part of their food; he has accordingly termed it *protein*, (from *πρωτεω*,[†] to hold a chief place.)

* Compounds consisting of the same elements in the same proportions, but with different properties, are said to be *isomeric*.—WEBSTER.

† Brande.

“Protein is obtained from albumen, fibrin, or casein, or from horn, by digesting them successively in water, alcohol, and ether, so as to extract all soluble matters; the residue is then digested in dilute hydrochloric acid, [*muriatic acid*,] by which the earthy salts are removed, and lastly, it is dissolved in a moderately strong solution of potassa or soda, which abstracts sulphur and phosphorus; this solution is then heated to 120°, and cold acetic acid is added in very slight excess, which throws down the *protein* in the form of a gelatinous precipitate, which is to be thoroughly washed with water upon a filter. Thus obtained, protein is a translucent, gelatinous, inodorous, and insipid substance, insoluble in cold and in warm water, and in alcohol, ether, and volatile oils; when dry, it is brownish, hard, brittle, and yields a yellow powder; it is very *hygrometric*, [that is, it retains a large portion of water,] but becomes perfectly *anhydrous* [free from water] when dried at 212°. When it is in this state digested in water, [soaked or softened,] it reassumes its original gelatinous appearance. When gradually heated to redness in close vessels, protein affords the usual results of the decomposition of nitrogenized organic substances, and leaves a bulky carbonaceous residue.”*

GELATIN and CHONDRIN.—These substances are characterized as containing a large relative proportion of nitrogen; but, unlike the compounds containing protein, their production is limited to the animal creation; they are, however, not found in the blood, but are exclusively products of secretion: they are nutritive; and are, in all probability, products of the change of protein on the one hand, and on the other, reconvertible into protein, by vital processes. When the skin and cellular and other membranes of animals, are boiled in water, the liquor cools into a gelatinous mass. A similar jelly may be obtained from bones, cartilages, tendons, and ligaments. The term *gelatin* was long indiscriminately applied to all the substances thus obtained, until MULLER pointed out the peculiarities of the product derived from *cartilage*, and appropriated to it the term *chondrin*.

* Brande.

It is generally assumed, though not perhaps on very sufficient grounds, says BRANDE, that the animal substances from which it is derived do not contain ready formed gelatin, but that it is generated by the action of hot water upon the membranous tissues.

Common *glue* is dried gelatin, in its crude state, as derived, by boiling, from the above named substances. The purest form of gelatin is the *isinglass*, so largely consumed in the preparation of jellies for the table. It is prepared from certain fishes, as the sturgeon, &c. Pure *gelatin* is colorless, transparent, inodorous, and insipid. It gradually softens and swells in cold water, but scarcely dissolves till gently heated, and on again cooling, the solution forms a more or less firm jelly. The most delicate test of the presence of gelatin, is *tannin*. It is the action of tannin upon the gelatin of the skins of animals, that renders them water-proof and indestructible by putrefaction. The solution of gelatin is not acted upon so as to precipitate it, by either sulphate of alumina or alum. *Chondrin*, however, is thrown down from its solutions by both alum and sulphate of alumina. Pure *chondrin* is obtained, by boiling, from the cartilages of the ribs, larynx, and joints of animals. A sugar called *glycocoll*, or *sugar of gelatin*, is prepared from gelatin.

Many elements, organic and inorganic, act upon these two substances, and also upon all those noticed in this chapter; but it has not been considered necessary to enter into the details, as those wishing to pursue the study more minutely, may easily refer to the chemical works which treat upon these subjects.

We may now close this chapter with a few remarks upon that class of the *proximate principles* of which it embraces a notice. Starch has the first place in it, only because the means by which it is procured, when stated, serves as a key to the processes for separating the other elements from the substances with which they are associated. But starch more properly belongs to the class of *proximate elements* included in the next chapter, which embraces those destitute of nitrogen, and is passed by for the present. The other proximate

elements already named, with the exception of protein, are called *albuminous* substances, to distinguish them from starch, sugar, gum, &c.; because, like albumen, they contain not only carbon, hydrogen, and oxygen, but also nitrogen, sulphur, and phosphorus. On account of this complex nature, the *albuminous elements* are very easily decomposed, it being impossible to prevent fermentation, putrefaction, or decay, if they are left exposed to the atmosphere. And if, while they are decomposing, they come in contact with other organic substances, they cause these also to enter into fermentation, decay, putrefaction, &c. As all vegetables contain more or less of these albuminous compounds, it follows that ample provision has been made, in their liability to decomposition, for the restoration of the constituents of decaying plants back again to the earth and atmosphere, that they may serve as elements for the production of a new growth of vegetation.

On the putrefaction of albuminous substances, their nitrogen, sulphur, and phosphorus, combine with hydrogen, forming *ammonia*, *sulphureted hydrogen*, and *phosphureted hydrogen*. The products of the decomposition of substances destitute of nitrogen, sulphur, and phosphorus, are very different from these, as will be seen when they are noticed. The above named gases are the chief cause of the very disagreeable odor which is given off during the decay, or putrefaction, of substances containing nitrogen, and especially of eggs, and other animal substances. During the progress of this decomposition, and escape of gaseous elements, there is also formed, as in the decay of woody fibre, a brown substance resembling *humus*.

However disgusting may be the products of putrefaction and decay, says STOCKHARDT, from whom we condense the foregoing remarks, they nevertheless contain within themselves the germ of the most beautiful compounds; the most beautiful plants arise from such products of decay. Indeed, the most nauseous-smelling decaying *nitrogenized* substances, are the best manures and the most powerful means of rendering our fields and gardens fertile.

But the above elements are not the only ones produced

by the decomposition of nitrogenized vegetable and animal substances. *Salt petre, nitre*, or the *nitrate of potassa*, is thus produced in the soils. To comprehend this point fully, take an example :

“ Mix some flax seed meal with wood ashes, sand, and lime, and let this mixture remain exposed to the air for several months in the summer season, frequently moistening it with water, and stirring it. If the mixture is then treated with hot water, and the solution evaporated, prismatic crystals will be formed from the latter on cooling, which will detonate smartly when thrown upon glowing coals ; they consist of *nitre*.

“ Here, also, *ammonia* is, in the first place, formed from the nitrogen of the *vegetable albumen*, present in great abundance in the flax seed meal ; but it is induced by the predisposing influence of the strong base, to undergo still further putrefaction : that is, to attract oxygen from the air, whereby *water* is formed from its hydrogen, and *nitric acid* from its nitrogen, the latter of which combines with its potash and lime.

“ In a similar manner *nitre* is often generated in arable land, whence it passes into the juice of certain plants ; thus it is known that beets and tobacco, growing upon very strongly manured soil, and also those rank plants growing on manure heaps, such as henbane, thorn-apples, &c., are frequently so rich in nitre, that when dried they emit sparks, if burnt on charcoal.”*

The reader will now be able to understand how *ammonia* is supplied to the atmosphere and soils, and to comprehend some of the uses of manures as fertilizers.

* Stockhardt.

CHAPTER V.

PROXIMATE ELEMENTS : — DEXTRINE—GLUCOSE—DIASTASE—CANE SUGAR—GUM—VEGETABLE MUCUS—PECTINE.

STARCH having been already described, it is only necessary, in noticing the *non-nitrogenized* constituents of plants, to describe the substances into which it can be changed.

DEXTRINE.—In its ordinary state, starch is insoluble in cold water, alcohol and ether, and only swells up in hot water. But when carefully heated till vapor rises from it, starch becomes soluble in cold and in hot water, and loses its gelatinous character. When thus altered by heat, it is known in commerce under the names of *British gum* and *dextrine*, and is used as a substitute for gum arabic, in the process of calico printing, and for stiffening different kinds of goods. A purer article than that obtained by the process of heating, is prepared by a method discovered by PAYEN. It consists in moistening 1000 parts of dry starch, (from potatoes generally) with a very dilute *nitric acid*, consisting of 2 parts of concentrated acid and 300 of water; the mixture is divided into small blocks, which, when dried in the air, are rubbed down, and exposed in a proper drying stove to a current of air heated to about 150° or 160°; the powder is ultimately well dried at a temperature not exceeding 230°. When well made, it dissolves in cold, or slightly warmed water, with the same facility as gum. This form of dextrine is called *seiocome*.

Dextrine may be prepared on a smaller scale, as follows : Mix thoroughly, in a small dish, half an ounce of starch with one dram of water and four drops of *nitric acid*; let the mixture dry in the air, and then place it on the hearth of a heated oven, which is just hot enough to hiss feebly when touched with the moistened finger. After some hours, all the *nitric acid* will be expelled, and the starch will dissolve almost entirely in cold water, and completely in hot water. Dextrine thus made is white, or has only a slight yellowish tinge.

But *dextrine* may be prepared by a still more speedy and simple process. Make a paste of starch by boiling potato starch with water, and, while yet hot, add to it, in a saucer, some drops of *sulphuric acid*, with constant stirring. That this acid effects a change is evident, for the viscid mass soon becomes a thin liquid. Now place the saucer on a jar, in which some water is simmering, which will serve as a steam-bath, and let it remain over the hot steam, the contents of the saucer *not being heated quite to the boiling point*, until the liquid has become semi-transparent. When this is the case, add prepared chalk, by small portions at a time, to the liquid, until it ceases to effervesce. The sulphuric acid will then have combined with the chalk, forming *gypsum*. The liquid must now be filtered from the gypsum, and left to evaporate in a warm place, when pure *dextrine* is the result.

GLUCOSE, OR STARCH SUGAR.—When dextrine has been properly prepared from starch, if it be dissolved in water, and boiled a sufficient length of time, with the addition of a little sulphuric acid, it is converted into a syrup, which, on being freed from the acid, and further evaporated, forms sugar of a *granular* structure. This product is called *starch sugar*, *grape sugar*, or *glucose*. It may also be obtained from honey, and the juice of several fruits, and forms the saccharine concretions found in raisins, and the efflorescence upon dried figs, plums, &c. In good seasons the expressed juice of grapes contains from 30 to 40 per cent. of solid matter, the greater part of which is *glucose*.

It will be noticed, in the process for preparing dextrine from starch, by adding sulphuric acid, that the liquid was not made to boil. To prepare sugar from starch, repeat the experiment, with the following deviation: Bring to brisk boiling two ounces and a half of water, to which twenty drops of sulphuric acid have been added, and then add one ounce of starch mixed with a little water, forming a paste, but only in small quantities at once, that the boiling may not be interrupted. When all the starch is stirred in, let the mixture boil for some minutes, then neutralize the acid by chalk, and evaporate the filtered liquid to the consistency of

a thick syrup. It possesses a sweet taste, and consists of a solution of sugar in water. The *starch syrup* thus made, as well as the white, solid *starch sugar*, easily prepared from it, are now both articles of commerce.*

Starch, as shown by these experiments, is converted by sulphuric acid, on moderate heating, into *gum* or *dextrine*, and on stronger heating, into *glucose*. In the latter case, also, dextrine is first formed, but this soon passes over into sugar. Accordingly, sulphuric acid exerts two different actions: by the first of which the starch is converted into gum, and by the second into grape sugar, or glucose.

Glucose is largely manufactured, especially in France, where it is sold as an article of commerce. Its usual source is potato starch, and for its extensive manufacture the following process is adopted: To 1000 parts of water there is added 10 parts of sulphuric acid, and 500 of starch. The dilute acid is heated by steam to between 212° and 220° ; and the starch, previously mixed to about the consistency of thin cream, with water of a temperature between 112° and 130° , is then suffered gradually to dribble in under constant stirring; its conversion into dextrine is immediate; in about two hours and a half the whole of the starch is added, and in from 15 to 25 minutes afterwards, the process is complete; the steam is then shut off, and the liquor transferred to another vat, so that the first may receive a new charge. In this second vat the acid of the liquor is carefully saturated with powdered chalk, thrown in by little at a time to prevent inconvenient effervescence. When the sulphate of lime has subsided, the clear liquid is drawn off and rapidly evaporated. To deprive it of coloring matter, and to improve its flavor, the syrup is passed, while hot, through filters of coarsely powdered animal charcoal, and farther concentrated by evaporation in a steam vat, when it is poured into shallow coolers and allowed to concrete.†

It has not yet been explained how this effect of the action of sulphuric acid upon starch, is produced. Starch, starch dextrine, and starch sugar, are also *isomeric* bodies, each

* Stockhardt.

† Brande.

having the same constitution; so that their difference undoubtedly depends upon a different arrangement of the atoms of carbon, hydrogen, and oxygen contained in them, and it is undoubtedly the sulphuric acid which effects this change in the position of the atoms. No portion of the sulphuric acid has been decomposed in the process, neither has any of it combined with the organic substance; for we find again, in the gypsum formed, exactly the same quantity of sulphuric acid that had been originally employed. Accordingly, in this case it exerts an action quite different from the usual action; it is an action like that of spongy platinum, which can excite a chemical activity in another substance, without itself undergoing any change. This peculiar mode of action of sulphuric acid and of platinum, is often designated by the name of "action of *presence*," (contact,) or action by *catalysis*, (power of conversion).*

Considered as an article of food, as a part of the diet of children and invalids, and as a component of our most nutritious vegetables, starch is very important, and several of its varieties are often resorted to medicinally. But, although eminently adapted to form part of our food, it is not fitted for exclusive nutriment, and this is the case with all those *proximate principles* of vegetables which are deficient in nitrogen: it is an aliment of respiration, rather than of nutrition.†

DIASTASE.—This element, though belonging to the class of *nitrogenized* substances, already noticed, is introduced here, because of its peculiar relation to starch. The singular manner in which starch is metamorphosed into other substances, as above noticed, is both curious and interesting. But the most remarkable conversion of starch into dextrine, and ultimately into sugar, is that which is effected by *diastase*. This element is produced in *germinating seeds*, and in *buds* during the period of their development; it is to the presence of this substance that the change of the starchy part of the seed into gum and sugar, during a certain part of its growth, is owing; and it is in consequence of the presence

* Stockhardt.

† Brande.

of diastase in *malt* that the brewer's *sweet worts* are produced, and that the addition of an infusion of malt to one of unmalted grain, is capable of converting a large portion of its starch into fermentable matter. Diastase was first obtained from barley malt by PAYEN and PERSOZ. It may be procured from brewer's malt, but in greater quantity from germinated barley, carefully prepared for the purpose, in which the germ has been allowed to attain about the length of the seed. As its ultimate composition is not known, with certainty, it has not been placed in our Tables, and the process by which it is obtained from the germinating barley and other seeds, need not be described. It is white, soluble in water, and in dilute alcohol, but insoluble in strong alcohol: its aqueous solution is tasteless, and soon becomes sour and decomposed. In this great tendency to decomposition, it resembles the *albuminous* compounds before noticed. Its effect upon starch is entirely destroyed by boiling.

Although diastase, as now prepared, cannot be regarded as perfectly pure, like that generated in germinating seeds, yet it nevertheless possesses a remarkable power of converting starch into dextrine and sugar: to such a remarkable degree, indeed, does it possess this power, that 1 part of it is capable of thus modifying 2000 parts of starch. The experiments made by GUERIN, to determine the influence of temperature upon the action of diastase, are very interesting. He found that at 68° there was produced from 100 parts of starch paste, by 12.25 of diastase, 77.64 parts of sugar. At 32° the paste was liquified, and 12 per cent. of sugar produced in it; and even at lower temperatures, namely, between 15° and 20°, starch paste was liquified by diastase, but dextrine only, and no sugar, was the result. This explains the reason why vegetables cannot grow at a low temperature—the starch of the seed cannot be converted into sugar, and the plant is thus left destitute of the aliment of growth.

If 1 part of starch be previously gelatinized by hot water, and added to 8 or 10 parts of water, containing a minute portion of diastase, and then gradually heated to between 160° and 180°, all the texture of the starch will be com-

pletely destroyed, its chemical peculiarities will disappear, the liquor contain dextrine and sugar, and the only residuary matter be a little woody fibre, traces of albumen, and of carbonate and phosphate of lime, and silica: of these the proportions vary with the kinds of starch, from about a hundredth to a thousandth part of its weight.

We have dwelt thus long upon starch, and the changes produced upon it by the action of other elements, because of its great importance in the vegetable and animal economy. On turning to Table XIV, it will be seen that the proportion of starch in the several grains, ranges from 32 to nearly 90 per cent. of their weight. By deducting the water from potatoes, which constitutes 75 per cent. of their weight, as stated in the Table, it will be seen that their solid parts are equally as rich in starch as the average of the grains. A notice of the agency which *diastase* has in promoting the growth of plants, will close our review of starch and its relations to other bodies.

But first, we must again refer to malt, as supplying a key to the understanding of this point. The remarkable change which *malt* communicates to starch, is to be ascribed to the *diastase* contained in the malt. Its power of converting starch into sugar, is of great importance to the brewer and brandy-distiller, as, in the manufacture of beer from barley or wheat, or brandy from rye and potatoes, the starch of these substances must always be converted into sugar, before fermentation and the consequent formation of alcohol can take place. In both cases, it is the *diastase* of the malt, indispensable in brewing and in the distillation of brandy, which effects this change in the so-called *mashing process*. The taste of malt is sweet and mucilaginous, and very different from that of the fresh grains of barley, because the conversion of the starch they contain into dextrine and sugar, commences during their germination, the further progress of which is arrested in this case by drying. But if the germinated barley is allowed to continue growing, as it does in the open fields, all the starch gradually vanishes from the grain, and passes, in the form of dextrine and sugar, into the juice of the young plant, as is obvious from

the sweet taste of the latter, and from its mucilaginous feeling when rubbed between the fingers.

A similar metamorphosis is also clearly to be perceived in potatoes. The quantity of starch contained in 100 pounds of the same kind of potatoes, (the proportion of water being about 75 per cent.,) has been found to be, in August 10 pounds, in September 14, in October 15, in November 16, in December 17, in January 17, in February 16, in March 15, in April 13, in May 10. Accordingly, the quantity of starch in potatoes increases during the autumn, remains stationary during the winter, and in the spring, after the germinating principle is excited, it diminishes. It is a well known fact, that on germination potatoes become soft, mucilaginous, and afterwards sweet; the dextrine forming from the starch renders them mucilaginous, and the sugar forming from the dextrine renders them sweet. The process of transformation advances still further in the earth, the potatoes becoming constantly softer and more watery, and when the starch is completely consumed in the growth of the young plant, the process of decay commences in the potato, and its products, carbonic acid, water, and ammonia, may be regarded as food for the somewhat older plant.*

Now, what is true of barley and potatoes, is true also of the other grains and roots. When they are fully ripe, and subjected to the action of moisture, at a proper temperature, germination commences, and *diastase* is elaborated in the swelling germ or bud. The *starch* of the seed or root is converted by the diastase, into dextrine and sugar, as food for the young plant, and when this office is performed, the diastase itself disappears.

One remark more, and we have done. Unripe apples and pears contain some starch, but when completely ripe the starch has disappeared, by being transformed into dextrine and sugar, imparting to them their sweetness of taste. It appears, also, that frost is capable of exerting a similar influence with that of diastase, upon the vegetable substances which are rich in starch and abundant in water,

* Stockhardt.

as frozen potatoes, apples, &c., have a sweet taste after being thawed.

CANE SUGAR.—This variety of sugar differs from *glucose*, or starch sugar, by the facility with which it crystallizes, and its pure and powerful sweetness; it is hence distinguished by the generic term *crystalline*, or *cane sugar*. It may be extracted from many vegetables, and is, in fact, contained in all those having a *sweet* taste. But it more particularly abounds in the sugar cane, the sugar maple, beet roots, and the stalks of Indian corn. The process of procuring the sap from cane by grinding and pressing, and from the maple by tapping, and the manufacture of sugar therefrom by rapid evaporation in boiling, need not be described. As to *beet sugar*, the process for its manufacture is briefly this: The roots, having been softened in water, are sliced, and the juice is expressed and boiled down to about two-thirds its bulk, with the addition of a little lime, when it is strained, again evaporated, and purified in the same way as cane sugar. Between 4 and 5 pounds of purified white sugar, besides a quantity of syrup, are obtained from 100 pounds of the root. The average expense, in France, of producing beet sugar, is between three and four pence the pound.

The action of acids upon cane sugar is complicated, and varies with their state of concentration and the facility with which they are decomposed, and impart oxygen. When cane sugar is dissolved in very dilute *sulphuric acid* and boiled, it is gradually altered and converted into that modification of sugar which is obtained by the action of the same acid upon starch, namely, *glucose*, or *granular sugar*. The same effect is produced by *muratic*, and also by *nitric acid*, under certain modifications of the process.

In addition to the change of cane sugar into glucose, by the presence of sulphuric acid, it is also affected by the vegetable acids. If a few drops of citric acid, or tartaric acid, be added to a thick boiling solution of sugar, it immediately becomes a thin liquid, which does not crystallize on evaporation. This result explains the reason why the sweet juices of fruits, in which organic acids are always present, do not yield, on being boiled down, a solid sugar, but only

a thick syrup. Sugar combines, in fixed proportions, with oxyd of lead, lime, and many other bases, which need not be noticed.

One ounce of cane sugar has the same sweetening capacity as two ounces and a half of starch sugar. The solubility of these two varieties of sugar in water, is likewise very different—starch sugar dissolving in it much less readily and more slowly than cane sugar. While one ounce of cold water can dissolve three ounces of cane sugar, it is able to take up only two-thirds of an ounce of starch sugar.

SUGAR OF MILK is that particular kind of sugar which occurs in milk, and imparts to it its agreeable sweetish taste. It is obtained in hard, white, crystalline masses, by evaporating the sweet whey. Sugar of milk is much less sweet to the taste than grape sugar, and requires six parts of cold water for its solution. It is well known that milk becomes sour by standing for some days; this is owing to its sugar being gradually converted into a peculiar acid, called *lactic acid*. It is composed of carbon 44.90, hydrogen 6.11, and oxygen 48.99, in 100 parts.

GUM ARABIC.—In many plants certain sorts of gum exist, and sometimes in such abundance that they exude from the bark as a viscid liquid, and harden upon it in transparent globular masses, such as we see on our peach and cherry trees. The name *resin*, by which these dried vegetable juices are frequently designated, is erroneous, because by resins are meant those vegetable juices which do not dissolve in water, but are soluble in alcohol. The action of gum is different, as it is insoluble in alcohol, but is softened and dissolved by water. The best known of these peculiar sorts of gum is *gum Arabic*, which exudes spontaneously from several species of acacia in Africa. In a chemical sense, only those sorts of gum are designated by the name of *gum* which dissolve completely in cold water, and thus form a clear transparent liquid. This is particularly true of gum Arabic. Dextrine, which has been already noticed as a product of the metamorphosis of starch, ranks as a *gum*, and is an intermediate substance between starch and sugar. Gum is one of the most widely diffused substances in the vegetable

kingdom, as it exists in greater or less quantities in the juice of every plant.

VEGETABLE MUCUS.—There is an exudation from the *tragacantha*, a shrub that grows in Greece and Turkey, which is called *gum tragacanth*. It will swell and soften into a stiff, viscid jelly, in cold water, but does not dissolve like dextrine and gum Arabic. It only *swells up* like starch, and if the mucilage is boiled, the mass becomes more uniform, but a complete solution is not effected. This kind of gum is called *vegetable mucus*, to distinguish it from the former; it occurs in many other plants, as, for instance, in the leaves of the mallows, and the coltsfoot, in the roots of the althea and salep, in flax and quince seeds, &c. This mucilage abounds in the cores of the quince, surrounding the seeds as a whitish transparent substance. Such is its abundance in this fruit, that one dram of quince cores is sufficient to convert half a pound of water into a thick mucilage. The gum of cherry and plum trees, being only partially soluble in water, is regarded as a mixture of gum and vegetable mucus.

Gum Arabic can be converted into *glucose*, like dextrine, by the presence of *sulphuric acid*. The process of its conversion into sugar, is the same as for changing dextrine into sugar.

PECTINE.—Currants, gooseberries, cherries, apples, carrots, &c., contain in their juices a peculiar kind of jelly, which is now known by the name of *pectine*. When boiled with sugar, it has the property of hardening into a gelatinous mass after cooling. It is prepared by carefully expressing the juice of the fruits named, and evaporating it more or less, at a temperature not exceeding 212° . It may also be obtained by the addition of alcohol to the recently expressed juice of ripe currants or gooseberries; when, in the course of a few hours, a gelatinous substance separates, which must be washed with weak alcohol and dried. It then resembles *isinglass* in appearance, and, when soaked in cold water, swells into a soft pulp somewhat like starch. It may also be procured from the rasped roots of carrots and turnips. Deposited from a mixture of one-fourth of the juice of cher-

ries and three-fourths of the juice of gooseberries, and washed carefully, first with dilute alcohol, and then with cold distilled water, it is pure, with the exception of a little coloring matter. The chemical analysis of pectine will be found in Table X, and its combinations with other elements may be learned from works on Organic Chemistry.

CHAPTER VI.

PROXIMATE ELEMENTS :—WOODY FIBRE—HORDEIN—ALCOHOL AND BEER.

WOODY FIBRE.—The cells and vessels of plants are composed of a substance termed *woody fibre*, *lignin*, *vegetable fibre*, &c. It forms what may be called the skeleton of plants, being, as it were, the fundamental material of their structure, and of the fabrics in which their various secretions and proximate principles are contained. It is to plants what bones, flesh, and skin are to the animal body, and imparts to plants their shape and firmness, forming the ducts and veins through which their sap circulates. It may be compared to the honey-comb, the wax composing the cells representing the woody fibre of the cells of plants, and the honey that fills the cells of the comb representing the sap of the plants. It is found very finely ramified, tender, soft, and easily digestible in the young leaves, flowers, and stems of plants, and in the pulp of fruits, and roots; hard and indigestible in straw, wood, and the husks of grain; solid like bone in the stones of plums, cherries, peaches, and the shells of nuts; light, porous, and elastic in the pith of the elder, and in cork; and lengthened and pliant in hemp, flax, and cotton.

The structure of plants may be thus stated: On the exterior lies the outer bark or epidermis. Inside this, lies the inner fibrous bark, consisting of lengthened tubes, which supply the place of veins for the circulation of the sap. From the inner bark of trees, towards the exterior, is deposited every year a new layer of bark, and towards the centre a new layer of wood. The light and whiter wood, lying next the inner bark, is called the *sap-wood*; but this, by the annually increasing compressure, becomes denser and more solid, and is then called *heart-wood*. This heart-wood is usually darker colored than the sap-wood, and is generally impregnated with coloring matter. The *tannin*, so useful in dressing leather, &c., is obtained from both the inner and outer bark of most plants.

To obtain pure *woody fibre*, common wood, usually in the form of saw-dust, is steeped in lukewarm water for a day or two. The liquid is then squeezed out through a cloth, and when subjected to the chemical tests formerly described as employed in the preparation of albumen, &c., it is found to contain vegetable albumen, gum, mucus, tannin, &c. These proximate elements are embraced in the sap which ascends in the cells of the woody fibre, or have been deposited from it within them, and are dissolved out by the water, while the woody fibre itself remains unaffected by that fluid. If the wood, or saw-dust, used in this first experiment, be next subjected to the action of alcohol, ether, lye, dilute muriatic acid, &c., additional substances, such as pitch, &c., will be extracted from it, and there will then remain the pure *woody fibre*.

As the substances removed from the wood during these processes, contain different proportions of organic elements, this fact will serve to explain the cause of the difference in the organic constituents of common wood and woody fibre, as is shown by their chemical analyses in Table II.

There are a number of forms in which *woody fibre* presents itself in a state approaching purity, as in linen, cotton, paper, &c., the bleaching processes having removed all soluble and foreign matter. Pure woody fibre is tasteless, white, and insoluble in water, alcohol, ether, and the oils. It is identical in its chemical constitution, with *starch*, *sugar*, *gum*, and *mucus*; being, like them, composed of *carbon*, *hydrogen*, and *oxygen*, the two last named elements occurring in all of them, *in the same proportions as in water*. This fact being stated, it will, of course, be expected that woody fibre may be subjected to changes, by chemical action, such as starch and gum are made to undergo. Accordingly, it is found that, on *boiling* paper, linen, or any other form of woody fibre, in *dilute sulphuric acid*, it is first converted into gum, and finally into sugar.* Of course the longer that linen and cotton goods are worn and washed, the nearer do they approach to pure woody fibre, and the more easily

* Stockhardt.

may the rags upon the children in the streets be converted, by the chemist, into sugars to please them and gratify their taste for confectionaries.

There are, however, other changes that can be produced upon woody fibre. When wood is carefully baked, so as to become of a pale brown color, it yields a brown infusion with water, which, when carefully prepared, tastes and smells like *toast and water*; and, indeed, woody fibre has been represented as convertible into a palatable and nutritious bread. Something of this kind is said to be used by the peasantry of Norway and Sweden, says BRANDE, and the following directions are given for the purpose by Professor AUTENREITH of Lubingen: he employed *beech* and similar woods destitute of turpentine: "In the first place, everything that was soluble in water was removed by frequent maceration and boiling. The wood was then reduced to a minute state of division, that is to say, not merely into fine fibres, but actual powder; and after being repeatedly subjected to the heat of an oven, was ground in the usual manner of corn. Wood thus prepared, according to the author, acquires the smell and taste of corn flour. It is, however, never quite white, but always of a yellowish color. It also agrees with corn flour in this respect: that it does not ferment without the addition of leaven, and in this case sour leaven of corn flour is found to answer best. With this it makes a perfectly uniform and spongy bread; and when it is thoroughly baked, and has much crust, it has a much better taste of bread than what, in time of scarcity, is prepared from the bran and husks of corn. Wood flour also, boiled in water, forms a thick, tough, trembling jelly, like that of wheat starch, and which is very nutritious."*

In the process above named, for converting woody fibre into dextrine and sugar, it is effected by *dilute* sulphuric acid and *boiling*. But BRANDE gives another process by which *concentrated* sulphuric acid, without the aid of heat, converts wood in the first instance into gum or dextrine, which may afterwards be changed into glucose. "Thus, if

* PROUT, as quoted by BRANDE.

about 100 parts of cotton, or shreds of linen, be gradually moistened with about 140 parts of concentrated sulphuric acid, so as to avoid evolution of heat and charring, they soon admit of being triturated into a mucilaginous magma, (or paste,) which is soluble in water; this solution, saturated with chalk and strained, yields a liquor from which alcohol throws down a gummy precipitate, and if this be washed with alcohol, redissolved in acidulated water, and boiled for several hours, it gradually passes into grape sugar. So that it might be inferred from these results, that woody fibre is convertible, by the agency of cold sulphuric acid, into *amidine** and *dextrine*, and afterwards into glucose. The evidence of the formation of starchy matter or amidine, in this case, is not very distinct; but if on the first action of the sulphuric acid on the cotton or linen, an aqueous solution of iodine be added, a deep blue tint is often obtained.† According to SCHLEIDEN, this apparent formation of starch is best effected by wetting clean cotton wool with water, squeezing it dry, and then spreading it in a flat dish and moistening it with a mixture of three parts of sulphuric acid and one of water; after about half a minute, add an aqueous solution of iodine, and the blue iodide of starch will appear.”

Any farther notices of the changes which woody fibre undergoes, by the action of other chemical elements, will be deferred until the subject of *manures* is discussed. Its ultimate organic analysis is given in Table XI.

In the foregoing description of woody fibre, we have followed the common and more recent authorities. By the term *woody fibre* we include all that portion of vegetables which is insoluble by the chemical agents above named. For a more minute description of the microscopic structure of the *membraneous* and *fibrous tissues* of wood, as combined in the formation of the cells of plants, and the relations they sustain to each other, the reader is referred to QUEKETT'S HISTOLOGY.

* Starch, on boiling and being diluted, separates into two parts, a transparent solution and an opalescent deposit; the first named is called *amidine*.

† Iodine is the reagent for testing the presence of starch: it always changes the solutions of starch to a blue color.

HORDEIN.—According to PROUT, barley contains a peculiar substance, insoluble in hot water, which he calls *hordein*, and which, during the process of *malting*, is diminished in quantity, and converted into sugar or starch. Hitherto hordein appears to have been confounded with starch. Its organic analysis is not given by BRANDE, from whom we quote. The proportion which hordein bears to the other proximate constituents of barley, is given in Table XIV.

This chapter may now be closed, by a few general remarks on the proximate elements which have been described within its limits, and by a notice of the production of *alcohol*.

Woody fibre, starch, gum, mucus, and sugar, are among the most widely diffused proximate elements occurring in the vegetable kingdom. They are present in all plants, says STOCKHARDT. Having neither acid nor basic properties, they are called *indifferent* vegetable bodies. There is a very great similarity in their constitution. They all belong to the non-nitrogenized substances, and, as before stated, contain only carbon, hydrogen, and oxygen: the two last elements always existing, in the whole of them, *in the same proportion as in water*, namely, in equal atoms; they are, therefore, composed of only *carbon* and *water*. They form a principal ingredient of all our vegetable food, and, accordingly, perform a very important part in the process of animal life.

On comparing *cane sugar* and *glucose*, it will be seen that they do not differ from each other, except that the latter contains a larger quantity of *water* than the former. BOUSSINGAULT represents the composition of glucose in this way, to show its relation to cane sugar:

Carbon	42.2	}	100 of cane sugar.
Hydrogen.....	6.2		
Oxygen.....	51.6		
Water	{ Hydrogen..... 1.8	}	15.8
	{ Oxygen.....14.0		
			115.8 of glucose.

It will be evident, then, that as cane sugar, as well as starch and gum, can be converted into glucose, all these

substances may be used for the same practical purposes, by their reduction to glucose. Now, as one of the purposes to which they are applied, in common, is to the manufacture of *alcohol*, it will be proper here to refer to the chemical process by which this important article is obtained.

ALCOHOL and BEER are produced by inducing vinous fermentation in the solutions, in water, of the substances from which they are derived. The term *vinous*, or *alcoholic fermentation*, is employed to signify the spontaneous changes which these solutions undergo, when placed under certain circumstances, and which terminate in the production of an intoxicating liquor. The principal substance concerned in vinous fermentation is *sugar*; and no vegetable juice can be made to undergo the process, which does not either originally contain it, or some other principle, such as starch or dextrine, capable of being converted into sugar. In the production of *beer*, the sugar is derived from the *malt*, and in that of *wine*, from the juice of the *grape*. The grape juice has the properties of *glucose*, and the starch of the barley is converted into glucose, by its *diastase*, before the *vinous fermentation* can be induced, or any alcohol generated. The sugar of honey, being identical with glucose, undergoes the vinous fermentation at once, when yeast is added to it, while at the proper temperature. As grape juice contains albuminous substances, along with its sugar, no yeast is needed to produce the vinous fermentation: it occurs spontaneously.

But if cane sugar be employed, the fermentation will not take place so soon, since it must pass into glucose before its decomposition into alcohol and carbonic acid can commence. This transition, it will be seen, takes place simply by the cane sugar receiving into combination with it an additional portion of water; and this result, it will be remembered, always takes place when a solution of cane sugar is placed in contact with certain acids. The acid in this case is supplied by the yeast employed. But to produce the vinous fermentation in cane sugar, requires a greater quantity of yeast than for glucose, as a portion of the yeast is first demanded to convert the former into the latter kind of sugar.

The change which the sugar experiences during this process, says STOCKHARDT, may be rendered very intelligible by comparing together the formulas of sugar, alcohol, and carbonic acid. It stands thus: 1 atom of *glucose* consists of 6 atoms of carbon, 6 of oxygen, and 6 of hydrogen. From this is formed: first, 1 atom of *alcohol*, consisting of 4 atoms of carbon, 2 of oxygen, and 6 of hydrogen; second, 2 atoms of *carbonic acid*, consisting of 2 atoms of carbon and 4 of oxygen.

Now, add the constituents of this alcohol and carbonic acid together, and they yield again the constituents of sugar. Thus sugar is resolved, by fermentation, into alcohol and carbonic acid. Both substances did not previously exist in the sugar, but they are new products of a peculiar decomposition of the sugar—peculiar for this reason, that they are exclusively made up of the elements of the sugar, without any thing being either subtracted from it or added to it. The yeast, or ferment, works also in the same peculiar manner; it induces a decomposition of the sugar, yet without combining with the sugar, taking anything from it, or giving anything to it; its mode of operation is analogous to that of sulphuric acid, when the latter converts starch into sugar. The action of the ferment, however, differs from that of sulphuric acid, just alluded to, since the ferment itself does not remain unchanged, but is also decomposed during the fermentation. Accordingly, two sorts of changes are going on by the side of each other, in the fermenting liquid: first, that of the nitrogenized ferment; second, that of the non-nitrogenized sugar. The ferment always commences the change, which is continued in the sugar, as if the latter were infected.

The best ferment is obtained from brewers' malt, and is composed of the *gluten* of the barley, which is dissolved during the mashing process, but in the course of fermentation is again precipitated as insoluble yeast. The quantity obtained from half an ounce of bruised malt, is sufficient to bring to complete fermentation the *wort* of a whole pound of malt. Its power of exciting fermentation is destroyed when it is rendered quite dry, or when it is boiled, finely triturated, or saturated with alcohol, &c.

When examined through the microscope, this yeast has exactly the form of simple vegetable cells ; and their increase in the fermenting fluid takes place in the same manner as in the most simple plants, new cells or buds developing themselves on each globule of the old yeast. These globules are hollow, and filled with a nitrogenized liquid, to which is to be ascribed the power of the yeast to excite fermentation.

When yeast is used, its particles are seen to become covered with small bubbles of carbonic acid, which cause them to rise to the surface of the liquor, where they discharge it ; and as they again sink, they gradually acquire a fresh coating of bubbles, which they carry up as before ; and in this way that motion of the whole mass of liquor is produced which is so characteristic of active fermentation, and which, provided a sufficiency of ferment be present, is maintained as long as any sugar remains to be decomposed. The process is also attended by a considerable elevation of temperature, and, when complete, the liquor clears, the yeast falls to the bottom, and the sugar has vanished, and is, as it were, replaced by alcohol. A trace of ammonia also, at the same time makes its appearance.

We shall not describe the process of *distillation*, by means of which the alcohol is separated from the watery fluid in which it is included ; but, with another reference to the properties of yeast, shall close our remarks on the class of vegetable products noticed in the present chapter.

It has been shown by several distinguished chemists, says BRANDE, that the *active part of yeast* is composed of minute vesicles, containing globules, and that these *germinate* in the solution of sugar, and produce a microscopic plant, of the order *fungi*, named *torula cerevisiae*. According to these authorities, the plant grows at the expense of the sugar, giving out carbonic acid and leaving alcohol. According to some, there are two species of vegetable seeds contained in yeast, which may be separated by diluting it with water ; in a few days globules fall to the bottom of the vessel, forming a gray pulverulent deposit which is extremely active in producing alcoholic fermentation when added to solutions of sugar ; but at the same time a film forms upon the surface

of the liquid, which consists of germs of another genus, the *penicillium glaucum*, having no power of exciting fermentation. These latter germs make their appearance in all acid albuminous liquids, and become *filamentous*, while the true producer of alcoholic fermentation always retains its distinct *globular* form. QUEKETT, however, speaks of the *penicillium glaucum* as being the fully developed plant, of which *torula cerevisiae* is but the early condition or germinating state, and says that TURPIN has demonstrated this to be true.

From 2 to 3 parts of pure yeast are required for the decomposition of 100 parts of sugar; and if there be excess of sugar, it remains unchanged after fermentation; so, also, if more yeast be present than is required for the decomposition of the sugar in solution, the deposit which ensues, when fermentation ceases, consists partly of broken and partly of entire cells. The broken, or ruptured cells, are no longer susceptible of vegetation or of inducing fermentation, but seem to have lost their vitality; while the unbroken ones retain those powers in full vigor, and afford evidence of it whenever they are brought into contact with solutions of sugar at a proper temperature.

CHAPTER VII.

PROXIMATE ELEMENTS :—FIXED OILS—GLYCERIN—GLYCERYLE—STEARIN—STEARIC ACID
—MARGARIN—MARGARIC ACID—OLEIN—OLEIC ACID—VOLATILE OILS, ETC.

FATS AND FAT OILS.—Under the head of *fixed oils*, PEIREIRA includes all fatty substances employed as food, whether obtained from animals or vegetables. The fats of vegetables are mostly liquid, and termed *oils*, those of the carnivorous mammalia and of birds are soft, and called *lard*, and those of the ruminating mammalia are hard, and named *tallow*. Animal fats, says STOCKHARDT, agree in their properties so exactly with the vegetable fats, that the subject will be rendered more intelligible by considering them together under the same head.

In vegetables, the oil is deposited principally in small cells in the seeds, and in animals it is lodged in the cells of the adipose tissue, which lie beneath the skin, and in the neighborhood of the kidneys, &c. The proportions of fatty matter range from *one* to *nine* per cent. in the common grains, and from *twenty-two* in flax seed, to *fifty-four* in olives, and *sixty* in filberts. Leaving out the main deposits of fat in the adipose tissue of animals, the proportions in their other parts range from 3.13 in cows' milk, to 3.89 in ox-liver, 14.3 in ordinary meat, and 28.75 in the yolks of eggs. The organic elements of fats and oils may be seen in the Tables.

The fixed oils, or fats, employed as food, are compounds of two, three, or more neutral saponifiable principles,* or *proximate elements*, named stearin, margarin, olein, butyrine, caprine, caproin, hircine, and phocenine. Each of these fatty principles is convertible, by a caustic alkali, into a fatty acid, a sweet substance, called *glycerin*, and *water*.

GLYCERIN is the sweet principle of oils, and is supposed to form the basis of fatty matter, is without color or smell, and of a syrupy consistence. It is soluble in water and

* Capable of being converted into soap.

alcohol, but not in ether, and dissolves baryta, strontia, and oxyd of lead. It is classed among the uncrystallizable sugary principles, not susceptible of vinous fermentation. It may be obtained in abundance in the process of making soap from the fats, by potassa and soda, as it remains in the liquor after the removal of the soap. It constitutes about a tenth or twelfth part of fats.

Glycerin is spoken of by some chemists as an *oxyd of glyceryle*, while others denominate it a *hydrated oxyd of glyceryle*. On this subject BRANDE makes the following remarks:

“It is assumed that *glycerin* is the oxyd of a hydrocarbon (*glyceryle*) composed of 6 atoms of carbon and 7 of hydrogen; but it is contrary to analogy that an oxyd, containing 5 atoms of oxygen, should be *basic*. STENHOUSE has inferred that the atomic constitution of glycerin, as it exists in combination with the fatty acids, is 3 atoms of carbon, 2 of hydrogen, and 1 of oxygen; and that when these compounds are decomposed, 2 equivalents of the glycerin so constituted, combine with 3 of water to form ordinary *hydrated glycerin*.* Some later experiments, too, of PELOUZE, quoted by Löwig, indicate the formula for hydrated glycerin, dried at 250° to 260°, as 6 atoms of carbon, 8 of hydrogen, and 2 of oxygen. The assumption, however, that glycerin is an oxyd of glyceryle, and that the fats and oils are proximately constituted of glycerin combined with the fatty acids, after the manner of saline combinations, is altogether hypothetical. BERZELIUS regards the fats as peculiar organic products, which agree in their susceptibility of being resolved by alkalis and other salifiable† bases, into fatty acids and glycerin, partly under *catalytic* influences, and partly as the results of *affinity*.”

The edition of Brande from which we quote, is that of 1848, and it seems that the true relation of glycerin to the fats was not then fully understood. STOCKHARDT'S Principles of Chemistry, published two or three years later, speaks, without any qualifications, of the *oxyd of glyceryle*, as the *base* of the fats and oils.

* See Table IX for the analysis of hydrated glycerin.

† Salt-producing.

Stearin, margarin, olein, &c., says PEREIRA, are probably *hydrated salts of glycerin*, as their analysis gives the following results :

	Called	Yields
1. Stearin,	Stearate of Glycerin -	Stearic acid and Glycerin.
2. Margarin,	Margarate of Glycerin,	Margaric acid & Glycerin.
3. Olein,	Oleate of Glycerin,	Oleic acid and Glycerin.
4. Butyrine,	Butyrate of Glycerin,	Butyric acid and Glycerin.
5. Caprine,	Caprate of Glycerin, -	Capric acid and Glycerin.
9. Caproïne,	Caproate of Glycerin,	Caproïc acid and Glycerin.
7. Hircine,	Hircate of Glycerin, -	Hircic acid and Glycerin.
8. Phocenine,	Phocenate of Glycerin, -	Phocenic acid & Glycerin.

Stearic, margarinic and oleic acids are without smell, and as they cannot be distilled with water, are called *fixed acids*. The other fat acids are odorous, volatile, and acrid. The peculiar smell, which most fats have, is due to one or more of these volatile oily acids.

It is necessary, to a clear understanding of this subject, to state the proportions in which the substances named occur in the more common fatty products. PEREIRA gives the following as the *per cents* :

The proportions of Solid and Liquid Fats in certain Fatty Matters.

	Olive oil.	Almond oil.	Cows' butter.	Hogs' lard.	Beef marrow.	Mutton marrow.	Goose fat.	Duck fat.	Turkey fat.
Stearin,	—	—	—	38	76	26	32	28	26
Olein,	72	76	30	62	24	74	68	72	74
Margarin,	28	24	68	—	—	—	—	—	—
Butyrine,	—	—	} 2	—	—	—	—	—	—
Caprine,	—	—		—	—	—	—	—	—
Caproïne,	—	—		—	—	—	—	—	—
	100	100	100	100	100	100	100	100	100

Hog's lard contains, besides stearin and olein, some margarin, but the proportion is not stated. The marrow of large bones, says Berzelius, is absolutely of the same nature as the other fat of the animal, so that the above table will afford a true idea of the general properties of beef and mutton tallow. The difference in the taste, between suet and

marrow, depends on the presence of substances in suet not included in the marrow. Mutton suet, for example, besides stearin and olein, contains some margarin, hircine and hircic acid. Hircine is most abundant in the feet of goats, from which it takes its name on account of its goaty odor. The oil from the blubber of the common whale consists principally of olein with some phocenine, and usually a little phocenic acid, to which it owes its odor. It also contains stearin. The oil from the spermaceti whale is more pure than the common whale oil, and deposits a substance called *spermaceti*. When this is triturated with alcohol, a little oily matter is abstracted and the residue is termed *cetine*. Palm oil has a considerable portion of stearin in its composition.

STEARIN is the *solid part* of fatty matters, from which the *oily part* has been separated. After melting, it concretes into a translucent, brittle, and friable crystalline mass. It is insoluble in cold water and cold alcohol, and yields margarin, margaric acid, and acroleine by dry distillation. Its organic elements are given in Table IX.

STEARIC ACID is obtained from stearin, by a series of tedious chemical processes, during which it is separated from the glycerin of the stearin, and from any margaric acid that may be mingled with it. When thus prepared, it is brilliantly white and translucent. Stearic acid is insoluble in water, but, like stearin, is soluble in boiling alcohol and ether. Its organic analysis gives it nearly the same constitution as stearin, the proportion of carbon and hydrogen being nearly the same, but the oxygen about one per cent. less. When stearic acid is subjected to distillation, it yields margaric acid and margarone, carbureted hydrogen, and carbonic acid gas, and water. It is also converted into margaric acid by sulphuric acid or chromic acid.

MARGARIN, it has been stated, is a margarate of glycerin. It is so difficult to obtain it pure, and so uncertain, that no analysis of it has been published in the works consulted by the author. It is solid, like stearin.

MARGARIC ACID can be obtained from olive oil, or any substance yielding it, by a process somewhat similar to that employed for stearic acid. Margaric acid is a white, ino-

dorous, tasteless, crystalline substance, insoluble in water, but soluble in boiling alcohol and ether. It falls in pearly scales as its alcoholic solution cools. The crystalline margaric acid has been repeatedly analyzed: its components are given in Table IX. Like stearic acid, it combines with a number of other chemical elements.

OLEIN has already been mentioned as the *oleate of glycerin*, and associated with margarin and stearin, in fats and oils. It is the leading ingredient in the greater number of the oils which remain fluid at common temperatures, and it is supposed that the properties of the *greasy* and of the *drying oils* are principally referable to peculiarities in their respective oleins; but perfectly pure olein, says BRANDE, has not been obtained. Olein is the fluid portion of fats and oils, which remains after the stearin and margarine have been separated from it. It is procured in a state approaching to purity, by separating, as far as possible, the margarin and stearin from a fat oil, by cold and pressure, dissolving the liquid portion in ether, evaporating and digesting the residue in cold alcohol, which dissolves the olein, and leaves the greater part of the remaining margarin and stearin undissolved. The olein is then separated from the alcohol by evaporation on a warm stove.

Olein is colorless, inodorous, and tasteless. The more perfectly it is freed from stearin and margarin, the more fluid it becomes and the lower the temperature at which it congeals. It is insoluble in water, but abundantly soluble in alcohol and in ether. Subjected to dry distillation it yields *sebacic acid* and *acroleine*; when long exposed to air it gradually thickens, absorbing oxygen and evolving carbonic acid.

OLEIC ACID is obtained from olein, by chemical processes which separate the latter substance from its base, glycerin, and from any other substances that may be present. Oleic acid is colorless, it has a slight odor, a somewhat acrid taste, and is insoluble in water, but easily soluble in alcohol. It is decomposed when subjected to distillation, yielding sebacic acid, carbonic acid, and a peculiar hydro-carbon, together with a carbonaceous residue. Its combinations with other chemical elements are numerous.

Fats are not *volatile*, and when spread on paper, or other porous substances, will not disappear. As they remain soft for a long time, we possess in them the means of rendering leather soft and flexible. They *float upon water*, and may be used for excluding air from other bodies. They are *insoluble in water*, and hence, may be used to prevent other bodies from being penetrated by water.

The similarity in the combustion of fatty matters and wood, indicates that they have a similar constitution. Indeed, both bodies possess the same constituents, namely, carbon, hydrogen and oxygen, the difference being that the fats contain more hydrogen and less oxygen than wood. They accordingly belong to one and the same category with alcohol and ether, namely to that of the *organic bodies which are rich in water*.

It has been stated that hydrogen is eminently combustible, while carbon burns with more difficulty—the former emitting *flame*, while the latter only rises to a *glow*. Thus, we can explain why fuel burns with a flame at the commencement of combustion, but finally only glows: it is the hydrogen which first burns with a flame, and afterwards the carbon with a mere glow, without flame. In this result we have the explanation of the reason why fatty matters, during combustion, produce more flame, in proportion to their bulk, than wood.

As in wood, so also in fats, the hydrogen burns more briskly than the carbon, and this is the reason why the partly burnt oil, remaining after the extinction of the flame, is richer in carbon and has a darker color. Linseed oil, on yet farther beating, becomes continually blacker, so that it finally acquires a viscid consistency, which when mixed with lamp-black, or ivory black, forms the printer's ink. Fats are combustible, but only at a temperature sufficiently high to effect their chemical decomposition. To secure combustion in the ordinary candle, the wick, formed of an easily combustible body, is employed, which on being lighted, melts the tallow and allows it, by capillary attraction, to ascend into contact with the flame and become heated.

Any further discussion of the properties of the fixed oils,

may be deferred, as more properly belonging to the arts and manufactures, than to agriculture. A description of the process by which fats are converted into *soaps*, by the action of the alkalies, may also be omitted here, and the chapter closed by a notice of the *volatile oils*, and some general remarks.

VOLATILE OILS. — The fats and fat oils, or fixed oils, are common to both vegetables and animals. Palm oil, indeed, resembles fat rather than oil, and is used by the natives of the west coast of Africa as a substitute for butter. The volatile oils, however, are of vegetable origin, and from that source they are obtained, whether used as perfumes or for medical purposes.

Whenever we perceive an odor in a plant, says STOCKHARDT, we may presume that a volatile oil is present, which gradually evaporates. But how incredibly diffused and diluted this must be, in many plants, may be inferred from the fact, that scarcely a quarter of an ounce of volatile oil is contained in one hundred pounds of fresh roses or orange blossoms. We most frequently find the volatile oils in the flowers and seeds, sometimes in the stalks and leaves, but more rarely in the roots. The oils are mostly obtained by distilling the vegetable parts with water, with the exception of the rind of lemons, oranges, &c., which yield their oils to pressure.

The sources of the volatile oils are numberless, but those in most common use are obtained from the rose, the orange, the lemon, the nutmeg, the almond, cinnamon, cloves, peppermint, lavender, bergamot, fennel, balm, mustard, juniper, laurel, wormwood, rue, turpentine, camphor, &c., &c.

Sometimes several sorts of oils are found in the same plant; as, for example, in the orange tree, the leaves of which yield one kind, the blossoms another, and the rind of the fruit a third.

All these oils are *volatile* at average temperatures, says the author last quoted, except camphor. If they are cooled, there is frequently separated from them a beautifully crystallized, solid, white, camphor-like substance, which Berzelius has called *stearoptene*, in opposition to the liquid portions

that remain, which are called *eleoptene*. Accordingly, the *volatile oils*, like the fixed fats, consist of two proximate constituents, one of which may be regarded as solid and crystallized, but the other only as a liquid. Many oils—for instance, the oils of roses and anise-seed—are so rich in stearoptene, that when kept in cool cellars, they congeal into a nearly solid mass.

The volatile oils are soluble in alcohol, and thus dissolved, many of them are used as cordials. They are also dissolved by *ether* and *acetic acid*, and may be mixed with the fat oils, to impart to them an agreeable odor.

All volatile oils are converted into *resin*, because they gradually absorb oxygen from the air, which first combines with a portion of the hydrogen of the oil, forming water, and then unites with the oil itself. The volatile oils are first converted by the air into *turpentine* and then into resins.* Oil of turpentine is composed of 10 atoms of carbon and 16 of hydrogen—or in *per cents*, according to Dumas, 88.4 of carbon, and 11.6 of hydrogen, in 100 parts:—Resin, of 10 atoms of carbon, 15 of hydrogen, and 1 of oxygen. The oil of turpentine, consequently, has only to relinquish one atom of hydrogen, and receive one atom of oxygen, to be converted into resin. This explains the reason why volatile oils become gradually viscous and scentless on being kept, and more rapidly in large and only partly filled bottles than in small ones. They are very rapidly changed by nitric acid into non-volatile, resinous substances.

FERMENT OILS.—Certain vegetables, namely, tobacco, the centaury-plant, &c., yield volatile oils, while undergoing the process of fermentation, either in water or in masses in the air. These are called *ferment oils*.

EMPYREUMATIC OILS are produced by dry distillation from both vegetable and animal substances: for example, oil of wood-tar from wood, coal oil from pit coal, animal oil from bones, oil of amber from amber, &c.

The action of air and oxygen upon the *fixed oils* has been carefully investigated by SAUSSURE. He found that the re-

* Stockhardt.

cently expressed fixed oils are scarcely affected by the action of the atmosphere; that after a variable period, however, of several months, but dependent upon temperature and exposure to light, they begin rapidly to absorb oxygen, and evolve carbonic acid and hydrogen. Under certain circumstances these changes may become so rapid as to be attended by inflammation, especially when the surface of the oil is greatly extended, as in the case of greasy cotton, tow, and cloths; and so many cases of spontaneous combustion have arisen from this circumstance, as to render precaution necessary, in shops and in all manufactories and establishments where danger can arise from such causes.* The so-called *drying oils*, linseed, hemp-seed, &c., appear to be the most susceptible of this species of oxydizement.

It is the opinion of some chemical physiologists, that the oil in seeds contributes to the production of heat during their germination, by undergoing oxydizement, and that they thus promote the more rapid growth of the young plant.

*Brande.

CHAPTER VIII.

PROXIMATE PRINCIPLES :—WAX—RESINS—EXTRACTIVE MATTER—COLORING MATTER.

WAX occurs in small quantities in all plants, especially in the shining coats of the leaves, stalks, and fruits; for instance, in the skins of apples, and particularly in the pollen of flowers. Some plants of Japan and South America, contain so much wax that it may be separated by boiling with water and by pressure, and it is then introduced into commerce under the name of *vegetable* or *Japan wax*. But the purveyors of our common wax are the bees, who gather it from the flowers, and use it in the building of their cells. Turpentine added to bees' wax, renders it more pliant and tough, and makes it more suitable for candles. Its analysis is given in Table IX.

RESINS. — It has been already stated that the volatile oils, when left exposed to the atmosphere, are acted upon by its oxygen and converted into *resins*. The principal sources of the common *rosin*, are from the pines and fir trees which yield turpentine. But the finest quality of turpentine is yielded by the American silver-fir, and is called *Canada Balsam*.

All the turpentines and balsams are to be regarded as solutions of resin in volatile oils, into which two constituents they are separated when distilled with water. The same thing happens when they are allowed to stand for some time in an open vessel, in a warm place, except that in this case the oil volatilizes and diffuses itself in the atmosphere, leaving the resin behind as a solid, brittle mass.

Resinous juices, from which the resins are prepared, exude from the trees spontaneously, or through incisions in their bark. Resins are also prepared by *roasting* the woods from which they are obtained. They may also be extracted from resinous plants by alcohol.

Resin, with a slight exception, is not soluble in water, but is soluble in alcohol and the volatile oils. The principal resins are the following: pine resin, copal, mastic, lac, ben-

zoin, dragon's blood, guaiacum, &c. Amber and bitumen are classed with the resins, though obtained from the earth.

Resins do not undergo decay, but have the power of protecting other bodies from decomposition. Though but slightly soluble in water, some of them contain it in a state of minute division. When this water is separated by heat from the resin of pines, they become transparent, and are then called *rosin* or *colophony*.

It is not necessary that we should enumerate the various uses to which the resins are applied. Their occurrence in vegetables, occasionally, can be accounted for, by the reader, when he is reminded that many plants contain volatile oils, which, on evaporation, yield resins. The analyses of rosin and bitumen are given in Table IX.

GUM RESINS.—There is another class of exudations from plants, half-resinous, half-gummy, which is called *gum resins*. Many plants in hot climates are especially rich in such resins, and from them the supplies of these substances are principally obtained. The principal varieties of gum resins are opium, aloes, myrrh, frankincense, assafoetida, gamboge, galbanum, euphorbium, and ammoniac.

These gum-resins can be separated readily into their two proximate constituents, as the gum is soluble in water and not in alcohol, and the resin soluble in alcohol but not in water. Most of these substances, besides gum and resin, contain a small quantity of volatile oils, to which they owe their peculiar odor.

INDIA RUBBER and **GUTTA PERCHA** are obtained from the exudations of a milky juice from certain trees in South America and the East Indies, which, on drying, yields the solid gum as it is furnished by commerce. The analysis of the India Rubber is stated in Table IX.

EXTRACTIVE MATTER.—It has been found, on closer examination of the vegetable juices, after the known substances, such as sugar, albumen, starch, &c., have been removed, that a brown or black uncrystallizable, soluble mass remains behind. This remaining extract generally possesses, in a greater degree than those removed, the taste and medicinal

effect of the plant from which it has been extracted. Wormwood and rhubarb have a bitter taste, henbane and pepper a pungent taste, the roots of liquorice and couch grass a sweet taste. When introduced into the stomach, wormwood is a *stomachic*, rhubarb *purgative*, pepper *stimulating*, henbane *narcotic*, &c. This substance is called *extractive matter*, and is distinguished by the following terms: bitter, aromatic bitter, acrid, sweet, narcotic, &c. The name, says STOCKHARDT, was obviously a very convenient one, since it applied to all the innumerable vegetable substances not thoroughly examined, which possessed a dark color and did not crystallize, however different might be their chemical constitution. How great this difference may be we infer from this, says he, that most vegetable substances, when they are boiled for a long time, or merely exposed to the air, owing to the ready changeableness of vegetable matter, are converted into brown, uncrystallizable compounds. But in modern times, several of these peculiar substances have been obtained in a crystalline form, consequently as fixed and independent compounds, some of which are named in Table XII, and will be more particularly noticed in considering the *vegetable bases* or *alkaloids*. The term *extractive matter*, then, is very indefinite, as to the properties that may constitute any such mass of matter yielded by plants. Extract of gentian, of columbo root, of quassia, &c., are substances of this kind.

COLORING MATTER.—When any of the extractive matters, above noticed, are themselves colored, or become so by the action of other substances, they are called *coloring matter* or *dyes*. The rich, varied, and delicate colors of flowers are so evanescent that they fade or disappear as the flowers wither, or if an attempt be made to obtain them by pressure or otherwise. A few plants, only, contain coloring juices of such permanency that they are more slowly decomposed by light, and may be extracted and employed for coloring other substances. These coloring juices are sometimes contained in the roots or the wood of plants, and sometimes in their leaves or fruit. But they are all turned white by chlorine or sulphurous acid, and may thus be removed, or bleached from any fabrics requiring that process.

The coloring matter of plants may be extracted in most cases by water, but sometimes it is only obtained by alcohol or other liquids. Some of these dyes may be obtained in a crystalline form, but others are known only in the form of extracts.

The most universally diffused of these coloring matters is *chlorophyle*, a name given to the green coloring matter of the stalks and leaves of plants. It is a mixture of wax and of several coloring matters, not well known. It is only mechanically mixed with the juices of the leaf, and is never present but where the plant is exposed to the light. Under the microscope it can be seen in some thin leaves, circulating in minute green granules among the juices of the cells.*

The other coloring matters furnished by vegetables need not be noticed. The organic analysis of indigo is given in Table XII.

It was remarked in a former chapter, that *alumina* has a great affinity for coloring matters. If logwood, or Brazil wood, be boiled for some time, and the colored decoction mixed with a solution of alum, adding thereto a solution of the carbonate of potassa, as long as any precipitate subsides, the hydrate of alumina is precipitated, and along with it the coloring matter of the decoction. These precipitates are called *lakes*.

To gain a clear conception of the principles upon which colors are fixed in fabrics of linen, cotton, silk, wool, &c., prepare a solution of alum, another of salt of tin, a third of green vitriol, a fourth of tartaric acid, and a fifth of carbonate of potassa, and saturate a sheet of white blotting paper with each solution. When dry, cut each sheet into three strips, smear one of the strips from each sheet with the decoction of fustic, another of logwood, and the third set with that of Brazil wood, and again dry them. It will be found that one and the same coloring matter produces a different color, or shade of color, upon each of the five sheets. This color will be very slight when the colored decoctions are applied to mere blotting-paper. If these dried strips be immersed in warm water, the

* Quekett.

colors will be for the most part dissolved from the last three tests, but not from the alum, tin and green vitriol. Those salts which, like the last three, have the power of forming insoluble combinations with the coloring matters, and fixing them firmly in the fibres of the cloth, are called *mordants*, and are generally employed by manufacturers to fix their dyes.

That which effects the coloring in fabrics, is the insoluble *lake* colors, that is, a combination of the coloring matter with alumina, peroxyd of tin, or sesquioxyd of iron, but which, in order that it may adhere firmly, must first be formed *within* the pores of the vegetable fibre, otherwise the colors may be rubbed off or washed out.

In *calico printing*, the mordants are only applied in spots, or else the whole of the cloth is first covered with the mordant, which is again removed in spots, by other chemical agents, that have the power to neutralize the mordant. When a piece of cloth thus treated is immersed in the coloring decoction, the coloring matter will be precipitated only in those places covered with the mordant, and thus, instead of one uninterrupted homogeneous color, an interrupted color is obtained, presenting a pattern.*

* Stockhardt.

CHAPTER IX.

PROXIMATE ELEMENTS :—ORGANIC BASES—VEGETABLE BASES, OR ALKALOIDS—ORGANIC ACIDS—ACETIC ACID—LACTIC ACID—BUTYRIC ACID—BREAD.

WHEN oxygen and carbon combine chemically, they form *carbonic acid*. When oxygen and calcium combine chemically, they form *lime*. The first named product is called an *acid*, and the second a *base*. When this carbonic acid and lime come in contact, they unite chemically, and form a compound called *carbonate of lime*, because it consists of carbonic acid and lime: the latter being the *base* of the chemical compound.

This statement will enable the unlearned reader to understand what is meant by a *base*, when the term is used in application to chemistry. All the *alkalies* are bases, and form compounds with acids. But as these alkalies are of *mineral* origin, they are called *inorganic bases*. When strips of spongy paper have been saturated with a decoction of litmus and dipped in an acid solution, their *blue color* is changed to *red*: but if this red paper be again dipped in an *alkaline* solution, the effect of the acid is destroyed and the paper again restored to its *blue color*. This is the common test for all acid and alkaline elements.

ORGANIC BASES, OR VEGETABLE BASES.—Among the vegetable products noticed under the head of extractive matter, there are many peculiar substances, which, like the inorganic bases, can combine with acids, forming salts. These substances are called *organic bases*, as many of them, like the alkalies, exert a basic reaction upon *red test paper*, changing it to *blue*. As these organic bases are charred and consumed by heat, while the inorganic bases are not, the former are called *alkaloids*, to distinguish them from the latter. *Alkalies*, then, are of mineral origin, and *alkaloids* of vegetable origin.

Almost all *organic bases*, says STOCKHARDT, dissolve with difficulty, or not at all, in water, but more readily in *alcohol*; their solutions have commonly a very *bitter* taste. As

a general rule, they dissolve much more readily in water, when combined with acids as salts, than they do when in their simple condition.

Most of the organic bases known at present, continues the last named writer, are derived from those plants which are characterized by their poisonous qualities or by their medicinal effects, and we have strong reasons for attributing to these bases the *poisonous* or *medical* properties of the plants. Many of them are virulent and dangerous poisons; but in very small doses they are energetic medicines. One grain frequently possesses the same medicinal power as an ounce, or even several ounces, of the vegetable substances from which they were obtained.

When the vegetable bases are dissolved, they are, almost without exception, precipitated by *tannic acid* as nearly or entirely insoluble *tannates*. For this reason, liquids containing tannic acid, such as tincture of gall-nuts, decoction of green-tea, or of oak bark, &c., are employed, not only as re-agents for detecting vegetable bases, but also as efficient *antidotes* in cases of poisoning by them.

The vegetable bases occur generally in combination with vegetable acids, and such other elements as are common to plants including acids. These bases can be separated from the vegetable acids, and extracted from the vegetable matter, by adding to the latter some water, and an acid which is stronger than the vegetable acid, and forms with the base an easily soluble salt. For this purpose muriatic acid, or sulphuric acid, is preferred. When one of these acids has combined with an organic base, if a *stronger base* be added to the solution, such as potash, lime, ammonia, or magnesia, the *organic base* is precipitated, while the strong acid and strong base form a new compound. It is on this principle that the formation of the different kinds of soaps is effected. The stronger bases, *soda* and *potassa*, displace the weaker *oxyd of glyceryle*, and combine with the *fat acids*, forming compounds of fat acids with soda or potassa: these products are the hard soaps and soft soaps in common use.

But we need not pursue these investigations any further. Table XII includes the analyses of a number of these vegetable bases.

ORGANIC ACIDS.—The acids which are found ready formed in vegetables are called *organic acids*, and occur in greater abundance than the organic bases. Several of these acids occur uncombined, or as acid salts, and produce the acid taste in unripe fruits and many other vegetable substances. They are also, in many cases, completely neutralized by bases, or are insoluble, as in the resins, and in both these cases they are not recognized by the taste. Besides these acids occurring in nature, many, also, have been discovered, which may be artificially produced from other non-acid vegetable substances; thus, oxalic acid and formic acid are prepared from sugar, acetic acid from alcohol, the fat acids from fats, &c.*

The vegetable acids have been denominated *organic acids*, to distinguish them from the oxygen and hydrogen acids, which are called *inorganic acids*. This term is applied to the latter class of acids, because they are principally found in the mineral kingdom, or prepared artificially from minerals and earths. *Citric acid* is abundant in the lemon, and is also contained in currants, gooseberries, raspberries, strawberries, the onion, potato, &c. *Malic acid* is found in the juices of unripe apples, in the berries of the mountain ash, and in the culinary rhubarb. *Oxalic acid* is also obtained in the rhubarb, along with the malic acid: one gallon of the juice yielding about 2.3 ounces of the latter and 6 drachms of the former. *Tartaric acid* is obtained from the grape, tamarind, &c.

The organic analyses of several of these acids are given in Table XI. They consist of carbon, hydrogen and oxygen. Nearly all vegetable acids consist of these three elements. Oxalic acid is considered as forming an exception, and containing carbon and oxygen only, but our table gives it near $2\frac{1}{2}$ per cent. of hydrogen, on the authority of GAY LUSSAC and THENARD. Brande says that absolute oxalic acid has not been isolated, and appears incapable of existing except in combination with water or some other base.

The organic acids cannot be prepared artificially from

* Stockhardt.

their elements, like the inorganic acids, though some vegetable acids may be also artificially imitated; but, as a general rule, this is effected by the metamorphosis of other vegetable substances. Like the vegetable *bases*, all vegetable acids can be charred and consumed by heat. The inorganic acids cannot be so consumed. Vegetable acids, like the mineral acids, unite with bases and form *salts*, and these salts are again liberated when the acid is decomposed by heat.

The *organic acids and bases* are derived from so many sources, and are so varied in their capacity for combining with each other, and with those of *inorganic* origin, that the method of their production, and their numerous transformations, cannot be enumerated in this work. As examples, however, we may state the process for the production of *acetic acid*, or common *vinegar*, and one or two other products.

ACETIC ACID.—Liquids which contain *starch* and *sugar* may be converted into *vinegar*, but not until after these substances have undergone the *vinous fermentation* and passed into *alcohol*. The formation of vinegar consists in an oxydation of the alcohol by the oxygen of the air. The formation of alcohol from *glucose*, it will be remembered, requires that the vinous fermentation shall remove a portion of the constituents of the sugar, from its solution, in the form of *carbonic acid*, and that when this is accomplished, the residue consists of alcohol and water, which can be separated by distillation. To convert *alcohol* into *vinegar*, the former must be made to combine with an additional portion of *oxygen*. To effect this oxydation of the alcohol, it must be diluted with water and some leaven added, and the liquid left exposed to the air at a temperature of between 86° and 104° , when, after some weeks, it will be converted into vinegar.

As the solution of sugar does not of itself pass over into alcohol, neither does the alcohol of itself pass over into vinegar. But as the yeast disposes sugar to enter into decomposition and produce alcohol, by parting with a portion of its constituents in the form of carbonic acid; so does a piece of *leavened bread*, *vinegar*, or *leaven*, added to the

dilute alcohol, bring it into that state in which it absorbs oxygen and passes into vinegar.

In the same manner, with pure diluted alcohol, other *alcoholic liquids*, such as beer, wine, cider, &c., may, by receiving oxygen, be converted into vinegar. And as they generally contain *gluten* or *lees* in solution, which perform the office of yeast, these liquids are all liable to pass spontaneously from the *vinous fermentation* into the *vinegar fermentation*. For this reason, in the hot months of summer, the brewers and brandy distillers find difficulty in keeping their fermenting *worts* and *mash* from turning sour.

This explains the reason why the farmer obtains vinegar from cider, or the peels and refuse of fruit; and why boiled food, preserved fruits, &c., become acid after a time. These substances all contain some *starch* or *sugar*, and also some *albuminous* substances. The spontaneous decomposition of the latter, it will be recollected, performs the office of *yeast*, and induces the *vinous fermentation* in the former, which, if not arrested, passes into the *vinegar fermentation*, and produces vinegar, or acetic acid.

The rapidity with which the transition of alcohol into vinegar takes place depends upon the extent to which the surface of the liquid is exposed to the air. For this reason the liquid is sometimes made to drip slowly through a porous shelf, near the top of a tub, down upon a mass of fine shavings at its bottom, and this minute subdivision of the liquid greatly hastens the production of the vinegar.*

LACTIC ACID.—When a liquid containing sugar, gluten, &c., is allowed to remain for some time at a temperature of 64° to 75°, it undergoes the *vinous fermentation* and alcohol is produced. But if a similar liquid, beet juice, for instance, be left to stand in an open vessel, in a warm place, where it will be heated to between 86° and 104°, it will enter into fermentation, and when the process is finished, notwithstanding all the sugar has disappeared, no alcohol exists in the fermented liquid. The process has converted the sugar into *lactic acid*, and along with it is found a mucilaginous,

* See Stockhardt for particulars.

gummy substance. This species of decomposition is called *mucilaginous fermentation*. Though the temperature is the same as that required for the vinegar fermentation in alcoholic liquids, yet as the beet juice has been at first raised from 86° to 104°, the alcoholic fermentation cannot take place, as it requires the temperature to be at from 64° to 75° only. As the alcoholic fermentation must always precede the vinegar fermentation, it follows, therefore, that vinegar cannot be produced in liquids where their fermentation occurs at a temperature above that which induces the vinous fermentation. In the production of lactic acid, carbonic acid is also produced, as in the case of the production of alcohol from sugar. Gum, as above stated, is also a product of this kind of fermentation.

The sugar contained in many vegetables likewise undergoes a change into lactic acid, when they are mixed with salt, and kept for some time in a compressed state. The acid taste in pickled cabbage, beans, &c., is owing principally to lactic acid. This acid is largely produced in the souring of milk.

BUTYRIC ACID.—Besides the lactic acid above mentioned, as produced in the pickles, another, called *butyric acid*, is also formed, which imparts to them their peculiar odor. This acid, it seems, may also be produced by the metamorphosis of vegetable mucus, for it is always generated when vegetable mucilaginous substances, such as quince cores, linseed, &c., are allowed to remain for some time in water. It is a constituent of butter.

BREAD.—In the manufacture of *white bread*, brewers' yeast is added to the flour, in mixing the dough. The sugar contained in the meal is thereby resolved into *alcohol* and *carbonic acid*, which struggle to escape, whereby the tough mass of dough is disintegrated, and rendered light and porous. These substances, together with about half the water employed, volatilize by the rapid heating in the oven, during the process of baking; and the cellular portions of the baked bread retain their form and place after cooling.

During the process of making *black bread*, besides alcohol

and carbonic acid, a little *acetic* and *lactic acids* are formed, and perhaps, also, some *butyric acid*.*

We may remark, in closing this chapter, that it will be observed, in noticing the Tables, that some plants yield *sugar*, and others *glucose*—that is, one class of plants yield *cane sugar*, and the others *grape sugar*. The cause of this difference is easily explained. Fruits contain *grape sugar*, which increases in quantity as they ripen or become less sour. In the *sugar cane*, the *beet root*, and the *maple* and *birch trees*, *cane sugar* exists, but in their juices no acid is associated with the sugar. On the contrary, ammonia is known to be present in most of them, along with the *cane sugar*. Hence, it is inferred that, as in our hands and in our experiments *cane sugar* is changed, by the agency of acids, into *grape sugar*, and with remarkable ease, by that acid which exists in the *grape*, so it is in the interior of plants. Where *sugar* occurs in connection with an acid in the juice of a plant, it is *grape sugar* in whole or in part, because in the presence of an acid body *cane sugar* cannot permanently exist, but is gradually transformed into the *sugar of grapes*, or *glucose*. It thus appears, also, why fruits so readily enter into fermentation, and why, even when preserved with *cane sugar*, they will, in consequence of the acid they retain, slowly change the latter into *grape sugar*, and thus induce fermentation.†

* For interesting details, see Stockhardt.

† Johnston.

CHAPTER X.

THE ORGANOGENS—NATURE OF COMBUSTION—DIGESTION—DECAY. HUMUS: ITS PRODUCTION AND RELATIONS TO VEGETABLE LIFE.

IN reviewing the ground over which we have now passed, so far as it relates to the *proximate elements* of plants, the reader will perceive that the four *organogens*, carbon, hydrogen, nitrogen and oxygen, constitute the main pillars of the vegetable world. Next to them, sulphur and phosphorus appear most widely diffused in the vegetable kingdom, since they form essential constituents of the *albuminous* compounds existing in all plants. These *organogens* are dissipated during the combustion of the bodies into the composition of which they have entered, and, resuming their *gaseous* form, again return to the atmosphere from which they were derived. The sulphur, during combustion, is partly converted into *sulphurous acid*,* which also escapes, and partly into *sulphuric acid*, which unites with one of the bases present (potash, lime, soda, &c.,) and remains behind in the ashes.

But while the *organogens* constitute the great bulk of the bodies in the vegetable and animal kingdoms, they cannot, alone, form any single plant or animal. It is essential to the existence of all such bodies, that, along with the *organic* elements which enter into their constitutions, there should be a portion of *inorganic* matter to serve as the basis of their superstructures. This inorganic matter, being indestructible by heat, it remains, after the combustion of organized bodies, as a residue, and we call it *ashes*. That the ashes of plants are composed of elements derived wholly from the earth, while the parts driven off into the air, during combustion, are derived from the atmosphere mainly, has already been

*This is the lowest form in which sulphur and oxygen combine, being one atom of sulphur and two of oxygen. *Sulphuric acid* is the common oil of vitriol, and consists of one atom of sulphur and three of oxygen.

shown. The term *ashes*, however, conveys a very indefinite idea of the chemical character of the residue of plants left by combustion. This will be made evident by examining the Tables, where the chemical differences in the ashes of various plants are stated.

It has been asserted, heretofore, that *combustion*, *digestion*, and *decomposition* are all chemical processes nearly identical in their operations and results. The terms *putrefaction* and *decay*, mean nearly the same thing as *decomposition*: the processes varying a little, but the effects being one. A tree falls into a pond or marsh, and sinks beneath the surface where the action of the air is partially excluded and it rots: the process is called *putrefaction*. But if a tree falls to the earth, and rots in the open air, the process is called *decay*. In chemical language they are both *decomposed*, and as fully so as though they were burnt.

It must not be overlooked that while combustion, digestion, and decomposition are identical in their operations and final results, they differ greatly from one another in the time necessary to accomplish the destruction of the body acted upon. By *combustion*, a few minutes or hours serve to decompose a plant and restore its organic elements to the air and the inorganic to the earth. In *digestion*, it takes hours or days to perfect the process. But in *decomposition*, weeks, months, or years are often required for the separation of the elements of organic bodies.

In reference to the identity of *combustion* and *digestion*, Prof. B. SILLIMAN, JR., remarks: "the carbon of the human body is as truly burnt in the lungs by the atmospheric oxygen, as is the fuel of our fires; and the product of the combustion, the *carbonic acid* thrown out by the lungs at every exhalation, is the same thing which is discharged at the mouth of a furnace. In the case of the animal body, the combustion is so slow that no *light* is evolved, and only that degree of *heat* (98° to 100°) which is essential to vitality. The term *combustion* must have, then, a chemical sense vastly more comprehensive than its popular meaning. The rust which slowly corrodes and destroys our strongest fixtures of iron, and the gradual process of decay which reduces

all structures of wood to a black mould (*humus*), are to the chemist as truly cases of combustion as those more rapid unions with oxygen which are accompanied by the splendid evolution of light and heat."

These remarks bring us to the consideration of the decomposition of organic bodies by the action of natural causes, and the restoration of their elements to the sources from whence they were derived. But another explanatory remark is here needed. Combustion and digestion differ in this: *combustion* at once makes a complete separation of the organic and inorganic elements of bodies, while *digestion* makes but a partial separation of them. The cause of this difference in the results of the two processes, arises from the fact that the *woody fibre* contained in the food of animals is combustible but not digestible. It accordingly remains unaffected by digestion, and passes off as *excrement*, along with the inorganic elements of the food. Were it otherwise and the woody fibre digestible, then the dung-heaps of the farmer would contain little else than what he finds in his piles of ashes. As it is, however, the Tables show that barnyard manures contain large per cents of organic elements, while ashes consist only of inorganic elements. Digestion, then, is more limited in its powers than combustion. But it is not the woody fibre only that escapes combustion during the process of digestion. All the *nitrogenized* portions of food, where digestion is complete, instead of undergoing immediate combustion, are transferred to the blood, as will be seen hereafter, and go to sustain for a time the tissues of the body.

But in the putrefaction, decay, or decomposition of organic bodies, the process is still different, in another respect, from combustion and digestion. The combustion of an organic body totally dissipates all its organic parts. In the digestion of such a body, its organic elements, as above stated, are mostly appropriated, by the animal functions, to the formation and support of the animal tissues: the indigestible organic parts and the unappropriated inorganic parts only being rejected and thrown off to mingle with the soil. In decomposition, however, all the organic and inorganic parts of bodies are left to the slow process of decay, during which

the greater part of their bulk, in many instances, becomes intermingled with the soil, and exerts an influence upon its productive powers. With these explanations, we are now prepared to proceed to the consideration of the decomposition of organized bodies.

HUMUS.—The *organic substances* contained in arable soil, says STOCKHARDT, have always a black or brown color, and are designated by the term *humus*. They partly consist of decaying leaves and branches, which have fallen off, and of decaying roots of plants remaining behind in the earth, and partly of decomposing vegetable or animal manure put upon the soil. These products of decay are gradually still further decomposed into carbonic acid, ammonia, and water, and for this reason they cause a more vigorous growth of vegetation. They likewise act favorably on vegetation, because, by reason of their dark color, the soil is heated more strongly by the rays of the sun, and they tend also to render the soil more loose and mellow. The presence of *humus* in the farmer's lands acts favorably in another respect, namely, by promoting the decomposition of the rocky parts of the soil, through the agency of the carbonic acid which is set free by the continuous decomposition of the vegetable substances composing the humus.

But the term *humus* is as indefinite as that of *ashes*, and both must be understood as used to designate a mass of chemical elements of unknown properties and proportions, except by chemical analysis. The *ash* of plants contains only their *inorganic* elements: *humus* consists mostly of their *organic* parts, but includes also the small proportion of inorganic elements that the living plant, from which it is derived, originally embraced. This subject, however, may be better understood by a more particular reference to the decomposition of wood, and it may serve as the representative of all plants.

Wood is subject to several kinds of decay, says BRANDE, some of which seem at first sight to relate merely to texture, whilst in others the changes are evidently of a more intricate nature, and terminate in the production of *humus*. When wood is preserved under cover in a dry atmosphere, or when

it is submerged in deep water, it is very little prone to change, and may remain unaffected for many centuries ; but under the joint action of air and moisture, it undergoes a series of successive changes, affecting both its form and composition. Under these circumstances it becomes *friable*, or easily crumbled, often of a pale or deep brown color, and, if moist, it converts the oxygen of the air about it into carbonic acid. The rapidity of these changes, and their concomitant results, depends much upon the nature of the wood in question ; that is, upon the quality and quantity of the foreign matters which may have been associated with it : the nitrogenized tending to promote and the resinous to retard the change. Beech, chestnut, and oak, as often seen in old forests or parks, or in timbers of buildings, furnish good specimens of this species of decay. Such specimens are of various shades of gray, or brown, and sometimes nearly black, and the resulting product appears to differ in composition with the circumstances under which it has been produced. But some farther explanations are here demanded.

It has been stated that *combustion* and *decay* are identical in their operations and results : that *combustible bodies*, in the common sense of the term, are those which burn under ordinary circumstances : that carbon, sulphur, phosphorus, &c., are *elementary combustibles*, or simple substances capable of being burned : and that tar, oils, wood, &c., are *compound combustibles*. The process of combustion, however, has not yet been fully explained. We find it thus described :

Combustion is the disengagement of light and heat which accompanies chemical combination. Nearly all our operations being performed in presence of the oxygen of the atmosphere, the term combustion has come to be restricted, in a popular sense, to the union of bodies with oxygen, when *heat* and *light* are accompaniments of such union. Oxygen being possessed of stronger affinities than any other elementary body, forms compounds with those bodies which are burned in it. In all cases of combustion the action is reciprocal. Hydrogen burns in common air ; but if a stream of oxygen is thrown into a jar of hydrogen, through a small aperture at the top, when the latter is burning, the flame is

carried down into the body of the jar, and the oxygen will continue to burn in the hydrogen, as it issues from the jet. In this case the oxygen may be said to be the *combustible*, and the hydrogen the *supporter*. The simple statement in both cases is, that oxygen and hydrogen combine together, and combustion—that is, the disengagement of light and heat—is the consequence. The diamond burns in oxygen gas, but the latter is as much altered by the union as the former, and we cannot, therefore, say whether the oxygen or the carbon is the most burnt.* Heat and light attend this union, and the product of the combustion is *carbonic acid*. If pure charcoal, which is carbon, be burned, the same result follows: the oxygen of the atmosphere, as in the burning of the diamond, combines with the carbon, and forms carbonic acid. The combustion of oxygen and hydrogen, as above noticed, produces *water*. The combustion of phosphorus also takes place on contact with oxygen, at a suitable temperature, and the product is *phosphoric acid*. The same results follow in the combustion of the other simple elementary bodies, an *oxygen acid*, corresponding with the element burned, being always produced.

But the burning of a *compound combustible* body produces results somewhat more complex than those of the simple elements above noticed. In the combustion of wood, its *hydrogen* is burned out sooner than its *carbon*. The reason of this has been explained: the hydrogen being more inflammable than the carbon is more rapidly consumed. Consequently, when the combustion of wood has proceeded for some time, where the oxygen of the air has not free access, as in charcoal pits, the hydrogen unites with the oxygen present, to a much greater extent than the carbon, and much of the latter is left unconsumed, when the former has all disappeared. Accordingly, if, at this stage, the charcoal pit be closed and the farther access of oxygen prevented, the combustion ceases, and the carbon of the wood remains in the form of charcoal.

If, in addition to carbon, hydrogen and oxygen, an organic

* Silliman.

body contains nitrogen also, it escapes uncombined, during the combustion, in the form of gas.

The process of *decay*, says PETZOLDT, bears a remarkable resemblance to that of *combustion*. Absorption of oxygen from the atmosphere takes place, and carbonic acid and water are formed in decay, exactly in the same way as in combustion, but without the appearance of flame; and the fact must be particularly noticed, that the hydrogen combines with the oxygen in preference to the carbon in decay as well as in combustion, and this necessarily causes the proportion of carbon in the residue to increase in the decaying substance, notwithstanding that a part of the latter also becomes oxidized and forms carbonic acid.

To render this intelligible, says the author last quoted, let us suppose woody fibre, in a moist state, exposed to the atmosphere for a considerable time. The oxygen of the atmosphere, in the first instance, will combine with part of the hydrogen of the fibre at its surface, forming *water*, and consequently, a corresponding amount of the oxygen and carbon, combined with this hydrogen in the fibre, will be liberated. Now, chemical experience has proved, that different substances combine with each other with greater facility at the moment of their liberation from other combinations (technically called their *nascent state*) than at any other time. This is precisely the case in decay: the oxygen and carbon are in contact at the instant they are liberated from woody fibre, in consequence of its hydrogen forming water with the oxygen of the atmosphere, and it is therefore in accordance with the general law of chemical combinations, that the carbon and oxygen thus brought into contact, should unite and form carbonic acid; and this under circumstances in which carbon alone does not usually combine with oxygen; as it is well known, that in order to burn a piece of charcoal, namely, to make it enter into combination with the oxygen of the atmosphere, and form carbonic acid, it is necessary to heat it to redness.

But we will explain this process of *decay* more minutely. Carbon and oxygen combine, and form carbonic acid, only in definite proportions. These proportions, as stated by

PETZOLDT, from whom we quote, are 27.65 parts by weight of carbon, and 72.35 parts by weight of oxygen. Now, vegetable fibre contains so much carbon, that even if all the oxygen present in the fibre combined with its carbon, and formed carbonic acid, it would not consume it all, and therefore, when all this oxygen is expended, a balance of carbon necessarily remains. Let us take the extreme case, that 100 parts of vegetable fibre undergo completely the process of decay; the result must be that after the 5.2* parts of hydrogen, in the fibre, have combined with atmospheric oxygen forming water, the 42.3 parts of oxygen of the fibre will combine with only 16.1 of the 52.5 parts of carbon present, forming carbonic acid, and thus leave 36.4 parts of carbon uncombined.

No instance, however, is known, where the process of decay has proceeded so far as to leave nothing but pure carbon. On the contrary, it is known that in all processes of decay, a period arrives when the carbon of the vegetable fibre begins to combine with the atmospheric oxygen, and after the lapse of a considerable time, it is all formed into carbonic acid, and nothing whatever remains of the vegetable fibre.† It is in this way partly that humus disappears from soils.

As in the preparation of charcoal by *combustion*, so in the *decay* of wood: the longer the decay has operated, up to a certain point, the greater is the *per cent* of carbon in the residue. The rate at which the oxygen of the air combines with the hydrogen of wood, as compared with that at which the oxygen and carbon of the wood combine, is thus stated by BRANDE: For every *two* equivalents of hydrogen oxidized by the air, *one* equivalent only of carbon is separated. Supposing this kind of *decay* to continue till the whole of the hydrogen had been removed, the final solid residue would be carbon only (as in the case of the preparation of charcoal by suppressed combustion); and this seems to have been the case in the formation of certain kinds of coal, which, like *anthracite*, are little else than pure carbon. In some in-

* These proportions correspond most nearly with the wood of Walnut, in Table XIII.

† Petzholdt.

stances, too, the decay of wood, under the joint action of air and water, leads to a similar result; for the black mud of shallow ponds surrounded by trees, and in which a large accumulation of dead leaves and wood has been allowed to rot and decompose, is found to contain a considerable proportion of charcoal.

The black mold, or *humus*, of rich alluvial soils, or of new grounds, is similar in its composition to the black mud of ponds. The black *muck* of swamps also possesses the same properties, and has been formed in the same manner with the black mud of ponds. All such deposits of *humus* are invaluable as manure for lands, if scattered over them and plowed under, to prevent the escape of their fertilizing properties.

When vegetable substances undergo decomposition in ponds, or where there is much moisture and not a free access of oxygen, the process, as before noticed, is called *putrefaction*, to distinguish it from *decay*, which occurs in the air. The process of *putrefaction* resembles that of *carbonization*, as in both there is an insufficient supply of oxygen present: and *decay* resembles *combustion*, in which there is a full supply of oxygen. LIEBIG calls *decay* a *slow combustion*.

The reader will now comprehend the processes by which *wood* is reduced by the action of oxygen into *humus*.

Plants, however, are made up of other matters besides woody fibre, and there is always present in them a portion of *proximate principles*, which include NITROGEN, as well as carbon, hydrogen and oxygen. The proportion of nitrogen in these proximate elements of plants, as shown by Table X, ranges from 15 to 18 per cent, and in animal substances, from 14 to 18. It is from the decomposition of these substances that *ammonia* is formed: it being a compound of nitrogen and hydrogen. Ammonia is invariably found in the humus of soils, ponds and swamps. As animal substances contain a much greater proportion of nitrogenized elements than plants, it follows, that animal matter adds the greatest proportion of ammonia to soils.

It will now be apparent that *humus* is identical with decaying organic matter, and that, therefore, it must include a

variety of distinct elementary substances, both *organic* and *inorganic*. The Tables of inorganic analyses will enable the reader, without repeating the statements here, to judge of the proportions and properties of the *inorganic* elements included in the humus derived from any single plant, or number of species of plants.

From the *organic* constituents of humus, several elements have been separated, which are of great importance in soils. Table XIII contains the analysis of humus itself, and of two of its products—*ulmic acid* and *humic acid*. Humus has a great preponderance of carbon, while its oxygen is one-half less than in wood. Ulmic acid has its hydrogen and oxygen in the proportion to form water. The terms *geine*, *ulmine*, *humic acid*, *ulmic acid*, &c., have been applied to the peculiar brown matter which may be extracted from humus. According to the analyses of MULDER, all the ordinary forms of these substances contain ammonia, and therefore yield *nitrogen*, as an ultimate element. They have consequently been represented, says BRANDE, as *salts of ammonia*, and a variety of formulæ have been imagined as the representatives of these compounds; but they are at such variance with each other, and so manifestly hypothetical, as to deserve no confidence. It will be best for us, then, to leave these doubtful points, and proceed to close our remarks on *humus*, by a more particular statement of its uses in promoting the growth of plants: merely saying here, that chemical changes are produced in its constituents by several of the alkalies and acids present in soils.

Humus possesses an extraordinary power of attracting moisture from the atmosphere, and of absorbing gaseous substances. It will imbibe water to the extent of three-fourths of its own weight without becoming moist,* and is therefore a fruitful source of the supply of water to plants. The farmer knows that lands which are dark colored, and consequently rich in humus, are more fertile than paler colored lands, and that the humus diminishes in his fields in proportion to the frequency and abundance of the crops they

* Petzholdt.

are made to yield. This operation, if not counteracted, he knows, will ultimately render his lands less productive, and hence he resorts to manuring and setting his fields in clover. By this course he adds *humus* to his soils, and keeps up their fertility. A single acre of land, cultivated in clover, and then plowed, has several thousand pounds of clover roots added to its soil. The roots, as well as the tops, thus mingled with the earth, soon rot and become *humus*.

The constitution of humus in the soils alters every day, says STOCKHARDT, since a little of its carbon and hydrogen is every day oxydized and separated. The humus generated by decay, as we find it in arable soil, he says, is now thought to be a mixture of several distinct brown substances,—namely, *ulmin*, *humin*, *ulmic acid*, *humic acid*, *geic acid*, *crenic acid*, and *apocrenic acid*,—which are produced consecutively, according to the above series, from vegetable matter. The two latter acids are soluble in water, and are partly the cause of the yellow or brownish color which we perceive in the water of marshes or bogs; the other three acids are only soluble in water when alkalies are added; finally, the first two substances, *ulmin* and *humin*, can neither be made soluble by water nor alkalies. Accordingly, by the general term *humus* we must understand a mass of brown decaying matter, partly soluble, partly insoluble, partly *acid*, partly *neutral*, which, with the uninterrupted presence of air, water, and heat, may be still further decomposed, and thereby *carbonic acid* and *water* evolved. Carbonic acid and water are indispensable in the nourishment of plants; hence, in a soil rich in humus, the plants will grow more vigorously, because they find there, and can absorb by their rootlets, more of these two nutritive substances than they could in a soil poor in humus. Humus exerts, moreover, a beneficial influence upon vegetation, because it loosens the soil by the development of carbonic acid; because it possesses the power of attracting water from the air, and of retaining it for a long time; and because, by means of the acids contained in it, it is able to abstract from the air, and also from manure, the third means of nutriment for plants, *ammonia*.

The reason why humus and manures, containing ammonia,

or nitrogenized substances from which ammonia can be formed, or substances which can absorb ammonia from the atmosphere, are so exceedingly valuable, is, because the nitrogen thus supplied, says Professor NORTON, is required to form *gluten*, and bodies of that class, in plants. Plants, he says, can easily obtain an abundance of carbon, oxygen, and hydrogen, from the air, the soil, and manures. Not so with nitrogen. They cannot get it from the air; there is little of it in the soils; and hence, manures which contain much nitrogen produce such a marked effect. Not that it is more *necessary* than other organic bodies, but more *scarce*,—at least in a form available for plants. The same reason applies to phosphoric acid. It is not more necessary than the other inorganic ingredients; but still is more valuable, because more uncommon in the soil and manures.

We shall close this chapter with a remark or two as to the relation which *humus* bears to vegetable life. It was at one time supposed, says BRANDE, that plants could feed upon soluble organic matters; and that the brown extract of a rich soil, or the liquor running from a dung heap, were in that way available as food for the growing vegetable, and that a great part of their carbon was derived from such sources. But we know that plants, instead of detracting from, add to the carbonaceous contents of the soil, partly by excretion from their roots, and partly from the autumnal fall and decay of their leaves and fibres; and that although the accumulation of decaying matter, which chemists term *humus*, performs an important part in vegetable nutrition, it is not by its direct absorption and assimilation, but by its influences as a source of carbonic acid, which is partly taken up by the juices of the root, and partly evolved into the atmosphere: so that plants, independent of their leaves, can thus receive carbonic acid. It would also appear, from the experiments of LUKAS, quoted by LIEBIG, that the action of humus may, under certain circumstances, be almost exclusively *mechanical*; that it may, for instance, be replaced by powdered charcoal, a substance in itself inert and insoluble, or, at most, only containing small portions of alkaline silicates, but yet administering to the wants of the plant, in

consequence of its extraordinary power of condensing carbonic acid, ammonia, and water, within its pores; for, when these bodies are present in the charcoal, the four *organogens* are there, for the support of the plant. In this way, plants not only grow, but thrive, blossom, and bear fruit, when planted in powdered charcoal, provided the influence of the rain and atmosphere be not excluded. On the other hand, a plant may die, though its roots are surrounded by the richest mold, if the access of air, and consequent production of carbonic acid, be cut off.

As this subject must again be alluded to, incidentally, when we come to consider the mode in which the vegetable kingdom appropriates the elements of its existence, we need not, at present, give it any further attention.

CHAPTER XI.

STRUCTURE OF PLANTS—THEIR APPROPRIATION OF THE ELEMENTS OF THEIR GROWTH
—INFLUENCE OF MANURES—PHILOSOPHY OF THE ROTATION OF CROPS—IMPOR-
TANCE OF THE ANALYSIS OF SOILS.

FROM the consideration of the nature, extent and sources of the supplies of vegetable aliment, we may next proceed to an examination of the mode by which plants appropriate the elements of their growth and perfect their structures. In this investigation references will have to be made, not only to the relations existing between the vegetable and animal kingdoms, but to the organic and inorganic elements of which the whole are composed.

The proportions in which the *proximate constituents* of plants exist in various articles of food, are stated in Tables XIV and XV. But the results there stated, as well as in the other Tables, must be taken only as close approximations. We have seen tables that give the proportion of fatty matter in Indian corn, as ranging from 5 to 9 per cent, while our Table places it at from 3.71 to 4.68 per cent. Variations exist in other articles, also, to such an extent, as to indicate that grains and roots are affected in their proportions of *proximate elements* by local causes, such as climate, soil, seasons, &c. These analyses, however, afford a sufficient index to the general properties of our common vegetables, and will serve as guides in the selection of articles of food, when a given result is desired in the feeding of stock.

We have elsewhere said that the chemical action of the organic and inorganic elements upon each other, in the soils, serves the purpose of *cooking* the food, as it were, upon which plants subsist. The point at present to be considered is, the appropriation of this *food*, by plants, in the process of growth. This will be best understood by considering first the structure of plants.

Among the circumstances connected with the structure of plants, says Prof. JOHNSTON, the organization of the leaf is of the greatest importance. The upper side differs essen-

tially from the under side; subjected to the magnifying power of the microscope this difference is very striking. The under part of the leaf is found to be studded with little holes, pores, or mouths, which sustain an important relation to the life of plants. They are very numerous, so much so, indeed, that on a square inch of a single leaf twenty thousand of these little pores have been seen and counted. The structure and number of these pores differ in different species of plants. By means of these they suck in aerial food from the atmosphere; and the mode in which they drink it in, and the quantity and circumstances under which they absorb it most favorably—that is, the circumstances of temperature and moisture—are related to the form and number of these pores, as they occur in particular kinds of leaves.

The structures of the stems of plants, and of their roots, are also important points to be considered. Some plants spread their roots over the surface to the distance of many feet, while the roots of others descend to a great depth. Wheat, for example, sends its roots to the depth of three or four feet into the soil, in search of food, and requires deep plowing to secure the best crops. An extended discussion of these points, however, is not intended here, and the reader is referred to the author above named, and to others who have written more particularly upon the subject.

The leaves of plants, by means of their innumerable pores, suck in the *carbonic acid* of the atmosphere during the day time, but not during the night. Carbonic acid, as before stated, is composed of oxygen and carbon, which, it will be remembered, constitute two of the *organogens* or main pillars of the vegetable kingdom. But the leaves, at the same time that they draw in the carbonic acid, discharge very nearly as much oxygen as they take in of oxygen in the form of carbonic acid; that is, if the leaf sucks in a given volume of the two gases combined, it discharges the whole of the oxygen and retains the carbon; the function of the leaf, therefore, is to suck in carbonic acid and throw off oxygen. But it retains the carbon, though not as charcoal; on the contrary, the plant exhibits green leaves, having no appearance of charcoal about them. The carbon undergoes certain

chemical changes, the result of which is, that the oxygen is given off, and the carbon becomes a new substance. This is one source from which plants derive the food out of which the proximate elements are formed. But in addition to the carbonic acid of the atmosphere, the *humus* of the soils is constantly affording a supply of this gas for the benefit of vegetation. Besides the action of humus upon the insoluble particles of rocks in the soils, and upon other elements existing therein, it is believed that plants derive some of their carbon from this source. In all ordinary cases, says Prof. NORTON, it is supposed that at least two-thirds of the carbon in plants comes from the air, and the remaining third in various forms from the soil. This is shown by the fact, that plants cultivated year after year cause the organic matter of the soil to diminish quite rapidly.

Plants require *hydrogen*, the third pillar of the vegetable world, as well as carbon and oxygen, from which to build up their structures. This element is readily obtained by them. Water consists of hydrogen and oxygen: in the form of a liquid the plants draw it up from the earth by their roots, or as a vapor it is absorbed from the atmosphere by their leaves. This may be seen, says Prof. NORTON, in the great effect of a trifling shower during dry weather. Even if there is only enough of rain barely to moisten the surface of the parched earth, the leaves, which had been drooping before the shower, are revived, and the whole plant assumes a flourishing appearance. This is the case, even where no water has reached the roots; the moisture, therefore, must have been absorbed through the leaves. Water, then, furnishes the supply of *hydrogen* to the vegetable kingdom.

Oxygen, says the last named author, is also to be obtained by the plant from water. Carbonic acid, too, it will be remembered, is partly composed of oxygen; and there is thus no difficulty in plants obtaining this element, and there can be no fear of exhausting it from the atmosphere.

Nitrogen is also one of the *organogens*, and the last of the four pillars above named, but the source whence plants derive their supply of this element is not so clear. We know, says Prof. NORTON, that four-fifths of the air sur-

rounding all plants is nitrogen, and yet it is proved that but little of any of this nitrogen is absorbed through their leaves : neither can it be shown to enter in any quantity through their roots. We find, however, he says, that the soil is the place from which it comes, but it is always, in some form, chemically united with other bodies. *Ammonia* and *nitric acid*, previously described as containing nitrogen, are the chief sources of its supply to plants : and this fact partly explains their great efficacy when used as manures. They are both present in fertile soils, sometimes the one and sometimes the other in large quantity. Both are *soluble* in water, and therefore can without difficulty enter by the roots.

It will now be apparent, that plants absorb their nourishment partly by the *roots* and partly by the *leaves* ; and it follows, that their food must either be liquid or aëriform ; for in these two forms only can it penetrate the fine pores of the root-fibres and the stomata of the leaves. Plants, then, we may conclude, receive their hydrogen and oxygen from *water*, their carbon from *carbonic acid*, and their nitrogen principally from *ammonia* ; but in what manner the assimilation of ammonia takes place in the vegetable kingdom, so as to impart its nitrogen to plants, is not yet fully known.

The fluids which are absorbed by the roots of plants, constitute the *crude* or *ascending* sap, and are circulated by the vessels heretofore noticed, throughout their stems, branches, and leaves, where they contribute to the formation of new parts, and to the composition of their various secretions. This sap is very dilute, and consists of little else than a watery solution of carbonic acid, ammonia, and traces of other salts, such as have been described as the inorganic constituents that enter into the composition of plants. This dilute sap is concentrated by evaporation, on reaching the leaves, and receives an addition of carbon from the carbonic acid of the atmosphere, which they are constantly absorbing.

The cause of the circulation of the sap, says BRANDE, is involved in great obscurity, enough only being known to render it probable that the chief ascent of the sap, from the roots to the leaves of trees, is through the vessels of the sap-

wood or *alburnum*; and, that having undergone the changes adverted to, it descends again from the leaves, chiefly by the inner layer of bark or *liber*, giving rise to the secretion of a glutinous substance called *cambium*, to the formation of new wood, and to the deposition or separation of gum, resin, and the other proximate principles which belong to plants and their fruits and seeds. The proofs of this circulation of the sap are, that if a branch be cut through in the spring, sap will exude more or less from its whole surface, but most copiously from the *sap-wood*; if it be cut half through, and a semi-cylindrical piece removed, the principal exudation of sap, upon the upper half, will then be in the inner layers of the bark, and the liquid which there oozes will be different from that which runs from the outer layers of the wood, and more concentrated: as if the *ascending sap-vessels* had been divided in the sap-wood, and the *descending* in the inner bark. Another fact confirming this view of the mode in which the sap circulates, and adds the materials of the growth of plants, in its *descent*, is this: If the branch or trunk of a tree have its bark cut through, upon one side, during the growing season, and a small space left bare, the proportion of new woody matter which is produced upon the upper side of the cutting is enormous, as compared with the lower side.

It is during this ascent and descent of the sap of plants, that the elaboration of all their *proximate constituents* takes place. The *organic elements* being presented to the leaves and roots in a liquid or gaseous form, plants can easily drink in, or absorb, this portion of their aliment. This is not the case, however, with their *inorganic elements*: these must be changed by chemical action, as they are mostly found, originally, in the state of solids, *insoluble* in water. But *soluble salts*, as we have seen, are always forming in the earth, from *insoluble* rocks. The term *rock*, as here used, includes not only the larger masses, but the smallest particles of undecomposed mineral substances. The salts thus rendered soluble, can be absorbed by the roots of plants as readily as they take up the liquids or gases. These inorganic elements are thus as fully supplied to plants, in fertile soils, as their organic elements are, from the soils and atmosphere.

It should be expressly stated, however, that a plant can grow vigorously, thrive, and attain complete maturity, only when all four of the *organogens* are presented to it *simultaneously*; and, even then, only when the *inorganic elements* are also present in a *soluble* state. For, if the latter elements are wanting in the soil, the seeds sown in it may indeed germinate, and grow for a while, because they contain within themselves a certain quantity of those inorganic constituents which the plants require for their growth, but the growth will cease when the constituents are exhausted in the development of the young plants. As the life of man ceases if only a single condition necessary for his continued existence is withdrawn, so also the complete development of a plant is obstructed when a single one of the above mentioned means of nourishment fails.*

If we give abundant and invigorating food to an animal, it becomes strong and fat; on scanty and slightly nourishing food, it remains poor and lean. The same thing occurs with plants. When they find an abundance of all the substances which they require for their development, in the soil and in the air, they will grow up more vigorously, and put forth more branches, leaves, flowers, and fruits, than when they do not find these substances, or find only a part of them in sufficient quantity. Consequently, the way of obtaining from our fields and meadows the largest produce, is to present to the plants cultivated upon them, *all* the materials requisite for their nourishment; and those in *sufficient* quantity.

But, while the atmosphere is a never failing source of supply of the organic elements of plants, soils do not everywhere contain all their inorganic elements in sufficient quantity or in such state as to be adapted to their wants. Nature provides, indeed, for the formation of *soluble* substances in the earth, by the gradual action of the weather; but these are not sufficient to yield a rich harvest, year after year, from the same fields, and it is therefore, sooner or later, indispensable to renew these constituents *artificially* in the soil, in order to maintain its fertility.

* Stockhardt.

Now, without here entering upon the discussion of the importance and value of manures, we may refer to a few facts connected with that subject. When soils have lost their fertility, for want of carbonic acid to decompose and render their mineral matter soluble, the best way, says Prof. NORTON, is to cultivate green crops for plowing under—such as clover, buckwheat, &c. The advantages of this process are easily seen. Though plants draw much of their organic parts from the soil, yet the greater proportion comes from the air through the leaves; consequently, when a crop of clover is plowed in, it carries with it, in addition to what it has taken from the soil, much more than half its weight of materials derived from the air, which is, therefore, so much clear gain to the soil. In this way the organic matter of soils may be increased, and even the poorest land gradually brought up to a state of fertility.

But when a tract of land is deficient in any inorganic element, or of the minerals which afford it, there is but one remedy; and that is, to add the element needed to the soil, separately or in combination with manures. All vegetable and animal *humus* contains more or less of *albuminous* substances, and will supply some sulphuric acid, phosphoric acid, and ammonia, to soils. But if phosphoric acid be demanded in larger quantities, then pulverized bones, bone ashes, animal charcoal, or guano, must be employed; and in this way any other essential element may be added.

It must be noted, also, that the *soluble salts* existing in food are removed again from the animal body by the urine of animals, while the *insoluble* pass off as solid excrement. This fact explains, very satisfactorily, the reason why the excrements of animals fed upon oats are the most appropriate manure for oats; those of animals fed upon peas, clover, or potatoes, the best manure for peas, clover, or potatoes.

We may also here further remark, in the language of STOCKHARDT, that since the *different* kinds of plants require *different* inorganic substances, and *different quantities* of them for their nourishment,—some, for instance, principally salts of potassa, others salts of lime, and others, again, phosphates or silicates,—so it is advantageous, in the cultivation

of plants, to make such a *rotation of crops*, that a potassa plant shall be followed by a lime plant, and this again by a silica plant, &c. In this way it is possible to obtain from a field, which is exhausted for one kind of plant, a second or a third crop, consisting of a different species of plant, without the necessity of manuring it each time.

From these hints the farmer will be enabled to comprehend the advantages of the *rotation* of crops, and to see that chemistry alone can give him a knowledge of the constituents of his soil, of the constituents of the plants which he wishes to cultivate upon it, and also of the substances which must be added to it in order that the plants may find there all that is necessary for their nourishment.

CHAPTER XII.

THE ANIMAL KINGDOM:—ITS RELATION TO THE VEGETABLE KINGDOM—DIGESTION—CHYME—CHYLE—ELEMENTS OF RESPIRATION—ELEMENTS OF NUTRITION—CIRCULATION OF THE BLOOD—EXHALATION OF CARBONIC ACID AND WATER—PRODUCTION OF ANIMAL HEAT—ALCOHOL—OXYGEN, ITS OFFICE IN THE ANIMAL ECONOMY—STARVATION, ITS EFFECTS—DEATH.

THE relation which the Earth and Atmosphere sustain to the Vegetable Kingdom, has now been noticed as fully as our plan will allow, and we shall proceed to that of the Animal Kingdom.

It will be evident from what has been said of the phenomena of vegetation, that the *functions of plants* consist in the *formation* of a variety of complicated products, out of the comparatively simple materials derived from the air and soil; and that the chief food of plants, independent of certain matters derived exclusively from the soil, may be said to consist of *binary** compounds of carbon, hydrogen, oxygen and nitrogen; namely, *carbonic acid, water and ammonia*.†

The *functions of animals* tend, on the other hand, to diametrically opposite effects from those of vegetables: the food of all animals, from the worm up to man, being either directly or indirectly of vegetable origin; and, as far as the *graminivorous* tribes are concerned, consisting exclusively of the complex products of plants. Thus, while the functions of vegetables, as we have said, are employed in forming woody fibre, starch, sugar, gum, albumen, gluten, casein, fatty matter, &c., out of *carbonic acid, water and ammonia*, the animal functions depend upon the progressive *resolution* or *separation* of these vegetable products into *carbonic acid, water, and ammonia*. That is to say, vegetables elaborate, or produce articles of food from the elements existing in nature; while animals decompose these articles of food and convert them back again into their original elements. In

* That is, compounds of two elements.

† Braude.

these processes, both plant and animal find their only means of subsistence. The plant, therefore, can exist without the animal, but not the animal without the plant. The animal cannot suck in the atmosphere and convert its *binary** compounds into the solid parts of its own body; neither can the plant live upon the *ternary* and *quaternary*† combinations which are required for the support of animal life.

The chemical processes, says STOCKHARDT, which take place in the living *animal*, are far more mysterious and more complex, than even those which take place in plants. That such actions really do occur in the animal body, who can doubt? We here see that which peculiarly characterizes these processes, the conversion of bodies into new bodies, with entirely new properties, far more distinctly and more forcibly than in plants and minerals. For example, can there be a more striking metamorphosis than that of the constituents of the egg, embracing albumen, yolk, and egg-shell, into the constituents of the young bird, consisting of flesh, blood, bones, feathers, &c.? or the conversion of milk, which constitutes the sole nourishment of many young animals, into flesh, blood, &c.?

That *chemical force*, alone, cannot effect these changes is certain; it is merely the instrument, the means, which the Divine Power has employed, in a way yet concealed from us, to form, *during the life* of vegetables and animals, all the different parts of the vegetable and animal kingdom. That which principally distinguishes animal life from vegetable life is, that during the former, oxygen is incessantly *inhaled*, but during the latter it is *exhaled*; and also that, with the exception of water and some salts, *organic substances only* are appropriated to the support of the animal, while a considerable portion of *inorganic substances* make up the vegetable.

But we must view this subject in another aspect. A living body, says PEREIRA, has no power of *forming* elements, or of converting one elementary substance into another; and

* See Table VI. † That is, compounds of *three* elements and of *four* elements: see Tables VII, VIII, IX, X.

it therefore follows, that the elements of which the body is composed, must be the elements of its food. The essential constituents of the human body are thirteen ; and the same, therefore, must be the elements of our food. They consist of carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, iron, chlorine, sodium, calcium, potassium, magnesium, and fluorine. Traces of silicon, iodine, manganese, and aluminum, are also met with in a few animal substances. Silica forms a principal element in the ash of plants, but only a trace of it can be detected in the ash of animal matter. The Tables, however, furnish the necessary information upon this subject.

The first operation which the food undergoes is that of *mastication*, and mixture with saliva ; and it is then propelled into the stomach, where *digestion*, as it is termed, commences. By digestion the elements are brought into a state of *solution*, and converted into an apparently pulpy mass, termed *chyme*, the theory of the formation of which has been much simplified by the results of modern research, which have taught us that the *proximate principles* concerned in the formation of the blood, and which are afterwards to build up the animal fabric, *preëxist* in the food ; and that the chief end of the function of *digestion*, is either to subdivide or *dissolve* them. This *solution* of the food has been shown by chemical physiologists to depend upon a sort of *fermentation*, or a metamorphosis analogous to it, under the influence of a nitrogenized principle resembling *diastase*.*

This subject has long engaged the attention of the learned, but we shall not enter upon the details of their experiments. All concur in showing, that the solvent powers of the *gastric juice* depend upon the joint agency of a peculiar *animal principle*, distinguished by the term *pepsin*,† and an *acid*, which is probably the muriatic acid, though phosphoric, lactic, acetic, and butyric acids appear to be sometimes present.

By digestion, then, the *nitrogenized* components of food, heretofore described, such as fibrin, albumen, casein, and gluten, are dissolved by the secretions of the stomach. Starch

* Brande.

† The analysis of *Pepsin* is embraced in Table X.

is probably converted into dextrine and glucose; gum and sugar, perhaps, undergo some analogous changes, and may possibly tend to the formation of lactic acid; and fatty matters are merely subdivided. To these we must add the liquids which are taken in with our food, the principal of which is water; and certain inorganic substances, which are chiefly salts of the alkaline and earthy bases, and oxide of iron. Amongst the former, common salt is preëminently important, as appears from its constant presence in the blood, and in many of the secretions, the eagerness with which it is sought after, and the maladies that arise out of its deficient supply; indeed, it is probably the chief source of the muriatic acid* and of the soda which are found in some of the secretions.†

LIEBIG observes, in reference to this subject, that the plants upon which *herbiferous* animals feed, cannot grow in a soil destitute of alkalies; but these alkalies are not less necessary for the support of animals than of plants. Soda is found in the blood, and in bile; and potash exists in the juice of flesh, and in milk; and phosphate of lime, which is essential to the healthy growth of the grasses, is equally essential for the production of bone.†

Here, now, are the substances which enter the stomachs of animals as food, are subjected to the process of digestion, and converted into *chyme*. The *chyme* passes from the stomach into the small intestines, where it soon changes its appearance, by becoming blended with *bile*, and is ultimately separated into two portions, one of which is white as milk, and is termed *chyle*: the other portion, passing on, is finally ejected as *excrement*.‡ Chyle has at first the appearance of a milky liquid, but in its passage through certain glands it acquires a reddish tint, and if removed, is spontaneously coagulable. According to TIEDEMANN and GMELIN, the *serum* of chyle is reddish-yellow, and the *coagulum*, at first pale, gradually acquires a vermilion tint. They ascribe its white opacity to the presence of globules of fat, the relative

* Common salt is the *chloride of sodium*, and muriatic acid is called also *hydrochloric acid*, as it is a compound of chlorine and hydrogen.

† Brande.

‡ For the chemical analysis of animal excrement, see Table XIII.

quantity of which depends upon the fat in the food.* We shall resume this subject again.

From the descriptions of vegetable products, in the preceding pages, it is evident that the food of animals includes two distinct series of *proximate principles*: those which are destitute of *nitrogen*, and those which include that element. The first class are composed of carbon, hydrogen, and oxygen, and are principally concerned in maintaining animal temperature, by a species of slow combustion, already noticed, terminating in the production of carbonic acid and water, which are thrown off by the lungs: these substances, therefore, have been termed *elements of respiration*. The second class consist chiefly of carbon, hydrogen, oxygen, and nitrogen, together with sulphur and phosphorus, and are employed for the formation of the principal organs of the body: these have been called *plastic elements of nutrition*. The *elements of respiration* include starch, gum, sugar, woody fibre, and fat; the *elements of nutrition* are the *proteiniferous* or *nitrogenized* products of vegetables, and their *congeners*,† the flesh and blood of animals. The importance of these distinctions will be apparent, as we proceed in this investigation; and it will be well for the reader to turn to the Tables of organic analyses, and note the bodies which contain *nitrogen* and those which do not: the former are the elements of nutrition, and the latter the elements of respiration.

We can now easily determine the chemical properties of the *chyme* and *chyle*, above noticed, by calling to mind the properties of the *proximate principles* of the food which has been eaten, and undergone the process of digestion and assimilation. On this subject STOCKHARDT says: "All of the *chyme* which has become soluble is, during its passage through the intestines, absorbed and introduced as nourishment, or *chyle*, into the blood. The changes which the food experiences in the animal body are, therefore, the following: from the *food* is formed *chyme*, from this *chyle*, from this *blood*, and from the blood all the numerous *organs and parts of the animal body are generated*, just as all the organs and parts of *plants* are generated from the vegetable juices."

* Brande.

† That is, substances of the same genus, kind, or nature.

As soon as an animal is released from its dependence upon the parent for sustenance, and begins to receive food into its stomach, this process of digestion and the formation of *chyme* and *chyle* begins, and the independent production of blood is commenced. As long as an animal lives, its blood is in a state of constant motion and of constant change; giving off its elements of nutrition as it courses through the system, wherever they are demanded to form, to complete, or to sustain, the various tissues or parts of the body. The writer last quoted, thus describes this process: "Light red blood streams out from the heart, through the arteries, into all parts of the body, from which it returns, darker colored, through the veins, back again to the heart. But before the latter blood recommences its circulation, it is impelled through the lungs, in which it comes in immediate contact with the inhaled air, and by means of which it experiences a most remarkable change. When in contact with the air, the dark venous blood is converted again into light red arterial blood, and thereby the *air loses a part of its free oxygen, and receives in return carbonic acid and vapor*; the *exhaled air* is accordingly poor in oxygen, but rich in carbonic acid and vapor."

Compare the composition of the air, before it goes into the lungs, with its composition when it comes out, and you will find that the air comes out charged with a greater quantity of carbonic acid gas than when it went in. In its passage through the lungs, the volume of this gas is greatly increased. This carbonic acid comes from the blood of the system; it consists of carbon and oxygen, and is obtained from the food. The animal, in fact, draws in air in its common form, and throws out air of a different composition; its oxygen is diminished, and its carbon increased.*

This change of the air in the lungs, is obviously very much like that which it undergoes by the process of combustion; for in this case, too, its free oxygen is converted into *carbonic acid* and *water*. Indeed, this similarity is rendered still more apparent, when we consider, moreover, that

* Prof. Johnston.

heat becomes free, also, in the animal body, as long as it lives and breathes, and that the food received into it, like wood in a stove, entirely disappears, with the exception of a small portion which passes off in the form of excrements. Its disappearance takes place exactly in the same way as that of wood with which we heat our apartments. This disappearance is caused by a change of the food into aëriform combinations; that is, into carbonic acid and vapor, which are partly exhaled by the lungs, and partly evaporated from the skin. For this purpose, as it seems, the *non-nitrogenized* articles of food are principally employed; namely, starch, sugar, gum, fat, lactic acid, and other organic acids, beer, wine, alcohol, &c.* These are the chief *elements of respiration*.

We shall not dwell upon the subject of the *transfer* of the fibrin, albumen, casein, &c., of vegetables, into the muscle, the blood, the hair, the skin and bones of animals, by the process of digestion, &c. It will be understood, from what has been said, that plants are merely a species of *manufactory*, as is well remarked by Prof. NORTON, where food is prepared in such a form, that the animal can build up its own body with the least possible trouble; and that, in eating meat, we only eat a more concentrated form of *nitrogenized* substances than can be had in a vastly greater bulk of vegetable diet. As, however, the offices performed in the animal economy by the *non-nitrogenized* elements above named, especially their supplying the *animal heat*, are not so easily comprehended, we must notice this point more at large.

By the union of carbon with oxygen, in whatever part of the system this is effected, *heat must be evolved*. At least, in all other cases, the formation of carbonic acid is attended with the evolution of heat;† and we have a right, therefore, to assume that the same takes place within the body. We are, in fact, acquainted with no conceivable reason why it should be otherwise. According to DESPRETZ, one pound of pure charcoal evolves, by its combustion in oxygen gas, sufficient heat to raise the temperature of 78 pounds of water

* Stockhardt.

* Pereira.

from 32° to 212°, which is from the *freezing* to the *boiling point*.

Now, the most abundant of the *elements of respiration*, in common vegetables, is *starch*. Carbon constitutes over 42 per cent. of starch. When speaking of the functions of the leaves of plants, it was stated that they draw in carbonic acid, and throw off oxygen; the carbon only remaining, and that in a new state of combination. Starch is one of the products formed from the carbon thus retained by plants. It consists of carbon and water only, its oxygen and hydrogen being in the proportions to form water,* so that, in forming starch, the carbonic acid absorbed from the air unites with water in the plant, and gives back its oxygen to the atmosphere. The function of the leaf, then, is to change this carbonic acid, and form starch; and so of gum, sugar, &c. The animal takes this starch into the stomach and decomposes it, and it escapes from the lungs in the state of carbonic acid and water; thus reducing the starch, as before stated, to its original elements. That water is given off from the lungs, is proved by breathing into a tumbler, when the cool glass is immediately coated with vapor, condensed from the breath. Proper tests show, also, that carbonic acid is *exhaled* from the lungs in large quantities.

The lungs, therefore, are continually exhaling carbonic acid and water, and these are thrown off at the expense of the food which the animal eats: that is, the starch which is conveyed into the stomach in the form of food, is, by certain animal processes, converted into carbonic acid and water, and thrown from the lungs. If a piece of starch be kindled, it will burn much like wood, and give out heat and light; and when it gives out this heat and light, it is converted into *carbonic acid and water*, or into the same things exactly as it is by the *respiration* of the animal. Thus, it is evident that the functions of animal life convert starch into the same substances which are produced when we burn it. The same effects are produced in relation to sugar, gum, fats, &c., as they have the same chemical constitution as starch.

* See Table XI.

This *combustion, digestion, or decomposition* of the starch, and other *non-nitrogenized* elements of food, in the animal body, is, then, the source of *animal heat*; or, at least, that is the present opinion of those who have investigated the subject.

In the natural and healthy condition of the system, the food supplies the necessary carbon for the support of animal heat; but when food is withheld, the *fat* of the body is consumed, its carbon being converted into carbonic acid, and its hydrogen into water. Hence results the emaciation attending long abstinence or starvation. The fat of animals, therefore, may be compared to the storehouses of fuel which are laid up for winter, when an increased amount of heat is needed, and daily supplies of firewood cannot be obtained.

Experience has shown, says PEREIRA, that the heat of the blood in health is the same in all climates and in all conditions of atmospheric temperature. Now it follows that a larger quantity of combustible matter is required in cold climates and in cold weather, for keeping up this temperature, than in hot climates and warm weather, since a greater amount of heat must be given off to surrounding media in the former than in the latter. Hence the necessity for a more liberal supply of food in cold weather and cold climates.

Different animals require very different quantities of oxygen, for the purposes of respiration. Man and warm-blooded animals consume the largest quantity; the amphibious tribes not only require less, but can breathe in an atmosphere which will not support the life of the former; and many insects take such small quantity, as sometimes to have been supposed capable of living without air, which, however, is not the case. In the production of carbonic acid, all animals unite; and, consequently, the nature of the deterioration suffered by the air is similar throughout the animal creation. Fishes breathe the air which is dissolved in water; they therefore soon deprive it of its oxygen, the place of which is supplied by carbonic acid: this is, in many instances, decomposed by aquatic vegetables, which restore oxygen and absorb carbon; hence the advantage of cultivating growing vegetables in artificial fish-ponds.*

* Brande.

PEREIRA says that part of the heat developed in carnivorous animals must arise from the oxydation of hydrogen; for, in the first place, hydrogen, (as of fat,) disappears from the system, and there is no other mode by which it can have done so, except by union with oxygen, and its consequent conversion into water. In the second place, he says that of the atmospheric oxygen taken into the lungs during *inspiration*, the whole is not found, in the inspired air, in union with carbon, nearly every experimenter having detected a loss.

We have spoken of starch, chiefly, in considering the mode in which the *elements of respiration* tend to keep up the *animal heat*, during their *combustion* in the animal system. The other elements—gum, sugar, fat, &c.—are consumed in the same way, as already stated, and also add their proportion to keep up the animal heat wherever they are present. There is one element of respiration, however, that should not be overlooked in this connection, on account of its moral bearing upon the mind, as well as its physical influence upon the constitution of man. We refer to *alcohol*.

It will be seen, by turning to Table XI, that *alcohol* is highly combustible, its carbon and hydrogen constituting nearly $65\frac{1}{2}$ per cent. of its components. Now, to understand fully the influence exerted by alcohol, in the animal system, we must again refer to the offices performed by the two classes of elements existing in our food: the *nitrogenized* and the *non-nitrogenized*. The nitrogenized substances *alone* supply to the blood the elements for building up and sustaining the different parts of the animal system, and are, therefore, called elements of *nutrition*. No parts of food, destitute of nitrogen, can add anything to the production of animal muscle, cartilage, &c. The non-nitrogenized substances in food, serve *only* as elements of *respiration*, and for the generation of animal heat. It is believed that the animal functions can transform sugar, starch, and gum, into *fat*,—which is, itself, one of the elements of respiration,—but never into muscle, cartilage, skin, &c., as they are destitute of nitrogen, sulphur, and phosphorus—elements which are essential to the production of these bodies.

To illustrate fully the point we have in view, it must be here noted, that the elements of *nutrition* and of *respiration* are so nicely balanced in their proportions, in all our common articles of food, that, for the diet of a healthy man, there is no necessity for adding an extra quantity either to the one class or the other. The supply of *nutrition* and of *animal heat* is so admirably equalized, in the consumption of common food, that any derangement of the proportions which it affords is attended with a corresponding derangement of the vital functions. If, then, to the proper quantity of food taken into the stomach we add a portion of *alcohol*, the respiration must necessarily be increased, and the animal heat augmented in a proportionate degree. Alcohol, as we have said, is highly combustible, and is an element of respiration, and not of nutrition. What, therefore, must be its effects upon the system? As the *chyle* enters into the circulation, and forms a part of the volume of the blood, to supply the wants of the human frame; so *alcohol* is also supposed to be conducted throughout the system, along with the blood, and to exert an influence upon the whole constitution. No part of the alcohol goes to form the tissues of the body, or to renovate and sustain them, as it is destitute of nitrogen, and, therefore, not an element of *nutrition*. It is obvious, then, that it can only serve as an element of *respiration*, to be *burned* in the body of the man, and to add to the amount of his *animal heat*. And what is the effect of this increase of animal heat upon his constitution? An insufficient supply of food, it is known, tends to produce *paleness* of the cheek, because both the *animal heat* and the *nutrition* are less than is demanded to keep up the healthful condition of the system. On the other hand, where age has not indurated the skin, an abundance of food keeps up the vital powers; and the face, possessing the *ruddy* color of health, bears testimony to a well-stored stomach. But when alcohol is added, in such a case, in excess, the nice balance between *nutrition* and *respiration* is destroyed, the healthful action of the animal functions is impaired, the ruddy glow of health disappears from the cheek, the *deep red* of the furnace heated by flame overcasts the countenance, and the secret habits of the

inebriate stand revealed ; demonstrating that a fire has been kindled in his breast that soon will consume the vital energies of the man.

In cases where the digestive organs are impaired by sickness, and sufficient food cannot be taken into the stomach to keep up the animal heat, alcohol is a very convenient and efficient agent to supply the deficiency, and secure a proper temperature of the body. "But," says PEREIRA, "though alcohol evolves heat in burning, it is an obnoxious fuel. Its volatility, and the facility with which it permeates membranes and tissues, enable it to be rapidly absorbed ; and when it gets into the blood, it exerts a most injurious operation on the brain and the liver, before it is burnt in the lungs. Though by its combustion heat is evolved, yet, under ordinary circumstances, there are other better, safer, and less injurious combustibles to be burned in the vital lamp."

While alcohol is exclusively an element of *respiration*, and all its modifications of brandy, rum, gin, and whisky, possess only this property ; beer and wine, not being the product of *distillation*, retain a portion of the elements of *nutrition*, belonging to the substances of which they are manufactured, and have been considered as less pernicious, on this account, than alcoholic drinks. In reference to their nutritive properties, however, says Baron LIEBIG, "we can prove, with mathematical certainty, that as much flour or meal as can lie on the point of a table knife is more nutritious than five measures (about 8 or 10 quarts) of the best Bavarian beer ; and that a person who is able daily to consume that amount of beer, obtains from it in a whole year, in the most favorable case, exactly the amount of nutritive constituents which is contained in a 5 pound loaf of bread, or 3 pounds of flesh." But we need not pursue this subject.

It must now be apparent that the primary conditions of the maintenance of *animal life* are a constant supply of articles of *food* and of *oxygen* in the shape of atmospheric air ; and that during every moment of life, oxygen is absorbed from the atmosphere into the organs of respiration, so that the act of breathing, and the consequent generation of animal heat, cannot cease while life itself continues. The amount

of oxygen thus taken into the system in one year by a man, is estimated at from 746* to 837† pounds, and yet his weight remains about the same at the year's end. This is an interesting fact, and the question will naturally arise, what has become of this oxygen? This seeming mystery is easily explained. No part of this oxygen remains in the animal body, but is given out again, *combined with carbon and hydrogen*. The carbon and hydrogen of certain parts of the body combine with the oxygen introduced through the lungs and skin, and pass off in the forms of carbonic acid and vapor of water. At every expiration and every moment of life, a certain amount of its elements is separated from the animal organism, having entered into combination with the oxygen of the atmosphere.‡ It is in this way, then, that the oxygen taken into the system, after serving as the supporter of combustion and generator of animal heat, again passes out of animal bodies.

A clearer view of the subject may be had by referring also to the amount of carbon taken into the system, and upon which the oxygen acts in the production of carbonic acid and of animal heat. The daily food of an adult man, taking moderate exercise, contains 13.9 ounces‡ of carbon, equaling 317 pounds in a year. To convert this carbon into carbonic acid gas, and allow it to pass off through the skin and lungs, requires 37 ounces of oxygen daily,‡ or 844 pounds in a year. There being also a constant supply of hydrogen in food, though in much less proportion than carbon,§ it likewise must have oxygen with which to combine and escape from the system as water. The hydrogen of the food, therefore, plays a not less important part than the carbon in the animal economy.

But to obtain the clearest views possible of the whole process of respiration, and the influence which the oxygen absorbed exerts upon the living animal body, we must consider the state of a man, or animal, totally deprived of food.

It has already been noticed that the starving man loses his fat, by its combustion, to keep up the animal heat. In

* Lavoisier.

† Menzies.

‡ Liebig.

§ See Tables.

the process of starvation, however, it is not only the fat which disappears, but also, by degrees, all such of the solids as are capable of being dissolved. For, in the absence of the elements of *respiration*, which are also supplied by the food, the oxygen after consuming the fat in the system, combines with other solid parts of the body and consumes them also.

Let us, then, note the extent of the chemical action necessary to reduce the human body, or that of any other animal, to its original elements by the deprivation of food. The whole amount of the elements of *nutrition* which are transformed into blood, and thence into the composition of the fleshy parts of the body, is derived from the food that is eaten. Cut off the supply of food, and no additional blood can be formed. The whole weight of blood in a healthy man is estimated at 24 pounds, of which 80 per cent. is water. From the known composition of the blood, it would only require 64.102* grains of oxygen, to convert the carbon and hydrogen of these 24 pounds into carbonic acid and water and remove them from the system. An adult man absorbs into his system 32½ ounces,† or 15.661 grains of oxygen daily; it would, therefore, require only four days and five hours, for the decomposition of the 24 pounds of blood, and for the speedy death of the man, unless new blood were produced by the supply of food, or some element of *respiration* taken into the stomach, to relieve the solid parts of the body from the action of the oxygen. By this means life might be somewhat prolonged.

In reference to death by starvation, LIEBIG says, that “in the wasted bodies of those who have suffered starvation, the muscles are shrunk and unnaturally soft, and have lost their contractility; all those parts of the body which were capable of entering into the state of motion have served to protect the remainder of the frame from the destructive influence of the atmosphere. Toward the end the particles of the brain begin to undergo the process of oxydation, and delirium, mania and death close the scene; that is to say, all

* Liebig :—French weight.

† Lavoisier :—French weight.

resistance to the oxydizing power of the atmospheric oxygen ceases, and the chemical process of *eremacausis*, or decay, commences, in which every part of the body, the bones excepted, enters into combination with oxygen.

“The time which is required to cause death by starvation,” continues LIEBIG, “depends on the amount of fat in the body, on the degree of exercise, as in labor or exertion of any kind, on the temperature of the air, and, finally, on the presence or absence of water. Through the skin and lungs there escapes a certain quantity of water, and as the presence of water is essential to the continuance of the vital motions, its dissipation hastens death. Cases have occurred, in which a full supply of water being accessible to the sufferer, death has not occurred till after the lapse of twenty days. In one case, life was sustained in this way for the period of sixty days.

“In all chronic diseases death is produced by the same cause, namely, the chemical action of the atmosphere. When those substances are wanting, whose function in the organism is to support the process of *respiration*; when the diseased organs are incapable of performing their proper function of producing these substances; when they have lost the power of transforming the food into that shape in which it may, by entering into combination with the oxygen of the air, protect the system from its influence; then the substance of the organs themselves, the fat of the body, the substance of the muscles, the nerves, and the brain, are unavoidably consumed. The true cause of death in these cases is the respiratory process, that is, the action of the oxygen of the atmosphere.”

Here, now, we may close this investigation. With the facts before him, the reader will be able, it is hoped, to comprehend the general principles of Animal Chemistry, and to understand that care is needed, in the selection of food, to secure a healthful action of the animal functions, and to prevent premature decay and death.

CONCLUSION.

OUR task is now nearly finished. It has formed no part of our design to attempt the production of a book that shall supersede the many valuable agricultural works heretofore given to the public, or to supply a substitute for the several instructive periodicals now devoted to the interests of agriculture, but only to present a more concise view of the great principles of the science than has yet appeared, and to show its relation to animal life. We shall, therefore, leave to the Editor the task of teaching the farmer how to prepare and apply manures to his soils, and how he shall best succeed in resorting to *rotations* in his crops.

This much, however, we must say: that *the analysis of his soils* is the first step necessary to be taken by every farmer who contemplates an improvement in his method of agriculture. Before he can know what is most needed to impart the greatest possible fertility to his lands, he must ascertain the elements which they already contain, so that he may add those only that are deficient in quantity.*

Table XVI. presents a sufficient number of analyses to show that both *soils* and *subsoils* greatly vary in the proportions of their elements; and that the absence of a single element—*phosphoric acid*, for instance—may have a most injurious effect upon vegetation, and, consequently, upon animal life. The importance of this or any other element necessary to the maturing of crops will be understood, in its relations to animal life, when it is stated that the body of an adult man is estimated to contain from 9 to 12 pounds of bones, which, on being burnt, yield from 6 to 8 pounds of bone ashes: and that these ashes contain from 5 to 7 pounds of *phosphate of lime*, and therefore include from $2\frac{1}{4}$ to 3

* Careful analyses of soils can be made, for Ohio, by Dr. Locke, of Cincinnati, Prof. Mather, of Columbus, and Prof. St. John, of Cleveland. Much care and chemical skill are demanded to make a correct analysis of soils, so as to detect all the elements present.

pounds of *phosphoric acid*. The phosphate of lime, composing the bones of all animals, is wholly derived from their food ; and hence the vast importance of this element to the agriculturist. The *guano*, now so extensively supplied by commerce, abounds in phosphates, and is, therefore, invaluable as a fertilizer of soils. The analyses of guano and other substances is given in Table XVII.

But enough has now been said to show the relation of the animal kingdom to the vegetable kingdom, and of both to the earth and atmosphere. We need not, therefore, detain the reader to sum up, at length, these diversified relations. If he will himself undertake the task, and contrast the functions of animals with those of vegetables, he cannot but be struck by the admirable adjustments which regulate them, and by which they are rendered mutually subservient and dependent. He will see that the food of the vegetable kingdom is principally administered to it in the form of water, carbonic acid, and ammonia : that these substances are decomposed in the plant, and that their ultimate elements,—carbon, hydrogen, oxygen, and nitrogen,—together with the inorganic elements derived from the soil, are elaborated by the vegetable organism into the proximate principles which serve as the food of animals ; that is to say, into all the modifications of the elements of *nutrition* and of *respiration*. In the animal system, on the other hand, he will observe that these proximate principles are successively resolved into more simple forms ; and, ultimately, during the life and at the death of animals, into the very carbonic acid, water, ammonia, and inorganic products, upon which the plants feed.

Thus will he perceive, that in the endless series of compounds produced from the simple elements existing in nature, by chemical action, under the control of *the laws of life*, there is no blank or interruption ; the first substance capable of affording nutriment to animals, being the last product of the creative energy of vegetables. And if he will take a wider view, so as to embrace the common rocks, precious stones, and metals, useful in architecture, arts, and manufactures, he will find that nothing has been made in vain, or

for nought; but that every element existing in nature belongs to the treasures which the beneficent Creator has laid up in store for the use of man; and that they are ceaselessly moving in one vast cycle, being combined, decomposed, and recombined, over and over again, in mineral, vegetable, and animal organisms, for the use of the successive generations of men.

The respective attributes of the vegetable and animal kingdoms have been well contrasted by DUMAS and CAHOURS, and we cannot do better than close our remarks by appending their very lucid contrast.

VEGETABLES	ANIMALS
<i>Produce</i> proteiniferous substances,	<i>Consume</i> proteiniferous substances,
“ fatty matters,	“ fatty matters,
“ sugar, starch, gum.	“ sugar, starch, gum.
<i>Decompose</i> carbonic acid,	<i>Produce</i> carbonic acid,
“ water,	“ water,
“ ammonia.	“ ammonia.
<i>Evolve</i> oxygen.	<i>Absorb</i> oxygen.
<i>Absorb</i> heat and electricity.	<i>Evolve</i> heat and electricity.
Constitute an apparatus of <i>reduction</i> .	Constitute an apparatus of <i>oxidization</i> .
Are <i>stationary</i> .	Are <i>locomotive</i> .

T A B L E I.

Chemical analyses of the minerals composing the Primary Rocks, from which the secondary rocks and the soils are derived.

NAMES OF THE ELEMENTS OF MINERALS.	FELDSPAR.			MICA.		HORNBLENDE.			Talc.	Steatite.	Serpentine.	Chlorite.	Chlorite slate.	Argillaceous slate.*	
	Common.	Labrador.	Albite.	Potash.	Lithia.	Magnesian.	Basaltic.	Syenitic.							Augitic.
Silica, - - -	65.21	55.75	69.09	46.10	47.7	40.00	42.24	45.69	53.36	62.80	65.64	41.95	32.68	31.54	56.11
Alumina, - - -	18.13	26.50	19.22	31.60	20.3	12.67	13.92	12.18	-	0.60	-	0.37	14.57	5.44	17.31
Potash, - - -	16.66	-	-	8.39	11.0	5.61	-	-	-	-	-	-	-	-	-
Soda, - - -	-	4.00	11.69	-	2.2	-	-	-	-	-	-	-	-	-	12.48
Lime, - - -	-	11.00	-	-	6.1	-	12.24	13.83	22.19	-	-	-	-	-	2.16
Magnesia, - - -	-	-	-	-	-	15.70	13.74	18.79	4.99	31.92	30.80	40.64	33.11	41.54	0.20
Oxyd of Manganese, - - -	-	-	-	-	‡4.7	0.33	0.22	‡0.09	-	-	-	-	‡0.28	-	-
Oxyd of Iron, - - -	-	‡1.25	-	8.65	-	19.03	14.59	7.32	17.38	1.10	3.61	2.22	5.97	‡10.18	‡6.96
Protoxyd of Iron, - - -	-	-	-	1.40	-	0.63	-	-	-	-	-	-	-	-	-
Oxyd of Magnesia, - - -	-	-	-	-	1.2	-	-	-	-	-	-	-	-	-	-
Chlorine, - - -	-	-	-	-	2.8	-	-	-	-	-	-	-	-	-	-
Lithia, - - -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carbonic acid, - - -	-	-	-	-	-	-	-	-	-	-	-	3.42	-	-	-
Fluoric acid, - - -	-	-	-	1.12	‡10.2	2.10	-	1.50	-	-	-	-	-	-	-
Titanic acid, - - -	-	-	-	-	-	1.63	-	-	-	-	-	-	‡1.02	-	-
Water, - - -	-	0.50	-	1.00	-	-	-	-	-	1.92	-	11.68	12.10	9.32	4.58
	100.00	99.00	100.00	98.26	106.2	97.37	97.06	99.53	98.01	98.34	100.05	100.28	99.73	98.02	99.80

* From a specimen of compact argillite.

† Peroxyd. ‡ Protoxyd.

§ Undecomposed matter.

|| Fluorine.

NOTE.—The above analyses of the Feldspars are from pure minerals, but the constituents of the several varieties are mostly found combined with each other. The sulphurets of iron are disseminated throughout all the geological formations, and supply the sulphur of the soils. Phosphoric acid is also combined with several minerals.

TABLE I.

Analyses of the Ashes, or Inorganic parts, of the Grains, &c., made from 1000 pounds of each.

INORGANIC ELEMENTS.	WHEAT.		RYE.		OATS.		BARLEY.		FIELD BEANS.		FIELD PEAS.		CLOVERS.		TIMOTHY HAY.*
	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Red.	White.	
Silica,	4.00	28.70	1.64	22.97	19.76	45.88	11.82	38.56	1.26	2.20	4.10	9.96	3.61	14.73	31.08
Alumina,	α 0.26	α 0.90	0.24	0.25	0.14	0.06	0.25	1.46	0.34	0.10	0.20	0.60	0.14	1.90	—
Potash,	2.25	0.20	5.32	0.32	1.50	8.70	2.78	1.80	4.15	16.56	8.10	2.35	19.95	31.05	24.25
Soda,	2.40	0.29	—	0.11	1.32	0.02	2.90	0.48	8.16	0.50	7.39	—	5.29	5.79	† 3.24
Lime,	0.96	2.40	1.22	1.78	0.86	1.52	1.06	5.54	1.65	6.24	0.58	27.30	27.80	23.48	14.94
Magnesia,	0.90	0.32	1.78	0.12	0.67	0.22	1.80	0.76	1.58	2.09	1.36	3.42	3.33	3.05	5.30
Oxyd of Manganese,	—	—	0.34	—	—	0.02	—	0.20	—	0.05	—	0.07	—	—	4.02
Oxyd of Iron,	—	—	0.42	—	0.70	0.02	trace	0.14	—	0.07	0.10	0.20	—	0.63	†† 0.27
Sulphuric acid,	0.50	0.37	0.23	1.70	0.35	0.79	0.59	1.18	0.89	0.34	0.53	3.37	4.47	3.53	4.46
Phosphoric acid,	0.40	1.70	0.46	0.51	0.70	0.12	2.10	1.60	2.92	2.26	1.90	2.40	6.57	5.05	11.29
Chlorine,	0.10	0.30	0.09	0.17	0.10	0.05	0.19	0.70	0.41	0.80	0.38	0.04	3.62	2.11	†† 0.70
Pounds of Ash,	11.77	35.18	10.40	27.93	5.80	57.40	23.49	52.42	21.36	31.21	24.64	49.71	74.78	91.32	99.55

α A trace of iron is included with the Alumina.

† Sodium.

†† Chloride of Potassium.

|| Peroxyd.

* The Timothy hay is from 100 parts of the Ash, by Profs. Way and Ogston. The other portion of the Table is taken from the Lectures of Prof. Johnston.

T A B L E I I I.

Analyses of the Ashes, or Inorganic parts, of edible roots, Indian corn, &c., as obtained from the proportions stated below.

NAMES OF INORGANIC ELEMENTS.	POTATO.		TURNIP.		CAR- PAR- ROT. SNIP.		RED BEET.		INDIAN CORN.		SUG'R BUCK- CANE. W'H.T. b		α HOPS.		
	Roots.	Tops.	Roots.	Tops.	Roots.	Tops.	Roots.	Tops.	Grain.	Stalks.	Stalks.	Grain.	Hop.	Leaves.	Vines.
Silica,	0.84	49.4	3.38	12.8	1.37	1.62	0.85	2.25	2.09	26.97	44.17	1.95	21.50	12.14	6.07
Alumina,	0.50	0.4	0.36	0.3	0.39	0.24	—	—	—	—	—	—	—	—	—
Potash,	40.28	81.9	23.86	32.3	35.33	20.79	13.10	7.70	26.63	9.62	16.03	21.27	25.18	14.95	24.35
Soda,	23.34	0.9	10.48	22.2	9.22	7.02	53.65	37.30	7.54	26.30	1.39	2.32	§1.67	0.39	§9.64
Lime,	3.31	129.7	7.52	62.0	6.57	4.68	1.50	10.25	1.59	7.39	10.09	3.01	15.98	49.67	38.73
Magnesia,	3.24	17.0	2.54	5.9	3.84	2.70	1.15	4.10	15.44	6.64	6.24	15.84	5.17	2.39	4.10
Oxyd of Manganese,	—	—	—	—	0.60	—	—	—	—	—	—	† 2.75	—	—	—
Oxyd of Iron,	0.32	0.2	0.32	1.7	0.33	0.05	*1.15	*3.75	0.60	0.81	—	—	*7.45	*3.51	*0.40
Sulphuric acid,	5.40	4.2	8.01	25.2	2.70	1.92	1.65	3.05	5.54	§1.19	5.79	1.55	5.41	5.04	3.44
Phosphoric acid,	4.01	19.7	3.67	9.8	5.14	1.00	9.85	8.20	39.65	17.08	6.14	49.85	9.80	2.42	6.80
Chlorine,	1.60	5.0	2.39	8.7	0.70	1.78	0.81	0.60	0.36	† 3.42	† 3.76	0.30	† 7.24	† 9.49	† 6.47
Carbonic acid,	—	—	—	—	—	—	16.27	21.90	—	—	4.66	trace	—	—	—
	82.83	308.4	63.03	180.9	66.19	41.80	99.98	99.40	99.44	99.42	98.27	98.84	99.40	100	100

* Phosphate of Iron. † Chloride of Sodium. ‡ Organic acids. § Sulphate of Lime. §§ Chloride of Potassium.

a Patent Office Report, 1850-51. b Dr. Salsbury.

NOTE.—The turnips, potatoes, carrots and parsnips, were weighed as taken from the field, and the Ash of 10,000 pounds analyzed, which gave the results above stated. The analyses of the red beet, Indian corn, sugar cane, buckwheat and hops, were made from 100 parts of the Ash of each. The cane is the average of four analyses, one of which, only, yielded soda.

T A B L E I V .

Analyses of the Ashes, or Inorganic parts, of the wood and bark of our common forest trees, in PER CENTS.

NAMES OF INORGANIC ELEMENTS.	SUGAR MAPLE. <i>a</i>			HICKORY. <i>a</i>			WHITE OAK. <i>a</i>			RED BEECH. <i>a</i>			PITCH PINE. <i>b</i>	SCOTCH FIR. <i>c</i>	RED BEECH. <i>c</i>	
	Bark.	Outside wood.	Heart wood.	Outside sap wood.	Heart wood.	Bark.	Sap wood.	Heart wood.	Bark.	Outside wood.	Heart wood.	Bark.				
Silica, - - -	0.15	0.50	0.55	*4.480	*1.300	*4.800	—	1.01	1.18	0.50	1.45	1.60	3.30	7.50	6.59	5.52
Alumina, - - -	—	8.77	4.21	7.472	12.210	2.340	13.41	13.41	9.68	0.25	12.13	4.04	0.13	14.10	2.20	2.33
Potash, - - -	7.75	0.97	—	0.084	0.055	0.125	0.52	0.52	2.57	—	15.58	25.53	—	20.75	2.22	22.11
Soda, - - -	49.33	31.86	43.14	33.264	43.520	51.105	30.85	30.85	43.21	54.89	31.56	31.32	52.29	13.60	23.18	3.32
Lime, - - -	3.64	8.40	7.24	6.200	4.000	0.820	0.36	0.36	0.25	0.20	5.44	1.44	0.82	4.35	5.02	25.00
Magnesia, - - -	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Phosphate of peroxyd of Iron, - - -	0.32	0.70	1.34	—	—	—	—	—	—	—	0.85	0.40	—	11.10	17.03	3.77
Phosphate of Lime, - - -	3.13	5.70	5.09	14.440	6.340	5.000	32.25	32.25	13.30	10.10	17.23	22.04	1.96	2.75	—	3.85
Phosphate of Mag. - - -	0.02	1.80	0.22	—	—	—	—	—	—	—	0.93	0.02	—	0.90	2.75	5.62
Sulphuric acid, - - -	1.49	1.16	1.08	0.892	5.260	1.925	0.12	0.12	0.26	0.03	0.47	0.62	—	3.45	2.23	7.64
Carbonic acid, - - -	37.12	37.25	33.33	29.576	33.630	33.935	8.95	8.95	19.29	29.80	24.39	24.59	40.41	17.50	36.43	14.00
Chlorine, - - -	10.08	—	—	0.096	0.065	0.145	4.24	4.24	0.47	0.12	1.06	0.24	—	—	—	—
Organic matter, - - -	1.50	2.40	1.98	un determined	—	—	5.70	5.70	7.10	1.16	1.86	2.80	1.50	—	2.80	1.84
Sodium, - - -	—	—	—	—	—	—	2.78	2.78	0.39	0.08	—	—	—	—	—	—
	105.41	100.51	98.16	101.504	106.390	100.255	100.18	100.06	100.00	100.00	111.99	115.14	99.91	96.00	100	100

a Prof. Emmons, Albany, N. Y. *b* Berthier. *c* Sprengel.
 * About one-fourth soluble. † Chloride of Sodium. ‡ Coal.

|| Oxyd of Iron. § Phosphoric acid. †† Oxyd of Manganese.

T A B L E V.

Analyses of the Ashes, or Inorganic parts, of our common fruit trees, the chestnut, g^c, in PER CENTS.

NAMES OF INORGANIC ELEMENTS.	PEACH TREE. <i>a</i>		CHESTNUT. <i>a</i>		BUTTERNUT. <i>a</i>		APPLE TREE. <i>a</i>			ROSE BUSH. <i>a</i>	STRAW-BERRY. <i>c</i>	
	Wood.	Leaves.	Outside wood.	Heart wood.	Outside wood.	Heart wood.	Bark.	Outside wood.	Heart wood.	Bark.	Wood.	Leaves and stalks.
Silica, (insoluble) -	1.35	6.42	1.43	1.71	1.20	4.40	0.80	0.45	0.20	1.25	8.00	6.117
Potash, - - - -	7.11	12.41	4.56	2.73	1.36	1.00	1.00	3.23	2.75	0.44	11.60	33.154
Soda, - - - -	11.16	1.20	1.41	1.98	0.32	14.82	11.27	3.33	1.63	1.63	5.99	2.790
Lime, - - - -	23.26	14.77	40.76	88.20	51.60	83.98	42.02	37.68	15.56	1.86	10.46	26.639
Magnesia, - - -	6.40	8.00	5.77	0.51	0.60	3.52	4.00	10.08	8.52	2.56	3.80	8.908
Phos. of perox. Iron,	0.32	2.47	0.30	0.80	0.20	3.40	8.41	0.30	—	—	—	—
Phosphate of Lime,	29.19	10.44	17.44	8.60	2.90	2.20	0.59	2.25	—	—	—	—
Phos. of Magnesia,	1.34	3.15	—	—	—	0.06	0.28	0.15	—	—	—	—
Sulphuric acid, -	0.51	12.12	0.50	—	0.31	13.33	21.43	0.74	12.21	22.17	6.00	1.469
Carbonic acid, -	—	—	23.84	29.52	39.90	20.02	4.48	32.12	16.79	38.98	16.87	23.008
Chloride of Sodium,	0.16	—	1.74	3.20	trace	0.13	0.15	0.33	0.51	0.30	3.00	1.708
Organic matter, -	5.20	0.86	0.91	1.76	1.00	3.40	2.80	3.20	3.60	3.35	2.30	1.739
Coal, - - - -	—	4.48	—	2.13	3.00	—	—	0.35	0.01	1.26	0.50	3.103
Moisture, - - -	—	—	—	—	—	—	—	—	—	—	—	—
	104.97	86.85	99.66	90.14	107.38	100.20	100.70	98.84	95.58	99.83	104.21	116 grs.

a Prof. Emmons. *b* Dr. Salisbury. *c* B. Kirtland, (from 116 grains of leaves and stalks, after bearing crop.)

† Chlorine.

‡ Organic acids.

†† Phosphate of Iron.

‡‡ Phosphoric acid.

§§ Charcoal and loss.

‡‡ And loss.

T A B L E V I I.

Analyses giving the proportions of Organic Elements and Ashes, in 100 parts of the Grains, edible Roots, &c.

NAMES OF THE ORGANIC ELEMENTS AND ASHES.	WHEAT.		RYE.		OATS.		FIELD PEAS.		BEANS.	POTATOES.		Turnip Root ^a		RED CLOVER.	
	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Peas.	Straw.		Root.	Tops.	Turnip Root	Beet Root ^a	Seed.	Hay.
Carbon, - - -	46.10	48.48	46.35	49.88	50.32	49.93	46.06	45.80	38.24	43.72	44.80	42.80	42.75	49.40	47.53
Hydrogen, - - -	5.80	5.41	5.58	5.38	6.32	5.32	6.69	5.00	5.84	6.00	5.10	5.54	5.77	5.80	4.69
Nitrogen, - - -	2.29	0.35	1.69	0.30	2.24	0.38	4.18	2.31	38.10	1.50	2.30	1.68	1.66	7.00	2.06
Oxygen, - - -	43.40	38.79	44.21	40.56	37.11	39.28	40.53	35.57	3.71	41.88	30.50	42.40	43.58	35.00	37.96
Ashes, - - -	2.43	6.97	2.37	3.68	3.98	5.09	3.14	11.32	3.90	3.90	17.80	7.53	6.24	2.80	7.76
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

† 14.11 per cent. of water is included in this analysis.

‡ Salts and earths.

^a Mangel Wurzel.

TABLE VIII.

Analyses giving the proportions, in per cents, of the Organic Elements and Ashes, in part, of Animal substances.

ORGANIC ELEMENTS & ASHES.	Muscular Fibre †		Ox Blood.		Skin.		Horn.		Wool.		Hair of Beard.		Hair of Head.*		Nails.		Tendons : Cat's foot.		Cat's ribs.		Mutton Fat.		Hog's Lard.		Human Fat.		Quill of Feather.		Beard of Feather.		
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		
Carbon,	51.83	51.95	50.99	51.99	50.65	51.53	49.34	51.089	50.96	50.20	78.99	79.09	79.00	79.00	52.427	50.434															
Hydrogen,	7.57	7.17	7.07	6.72	7.03	6.69	6.576	6.824	7.19	7.04	11.70	11.15	11.41	11.41	7.213	7.110															
Nitrogen,	15.01	15.07	18.72	17.28	17.71	17.94	17.986	16.901	18.82	14.80	18.82	14.80	18.82	14.80	17.893	17.682															
Oxygen,	21.37	21.39	23.22	24.01	24.61	23.84	26.143	25.186	23.53	27.86	9.31	9.76	9.59	9.59	22.467	24.774															
Sulphur,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—															
Ashes,	4.23	4.42	† (1.00)	† (0.70)	† (2.00)	† (0.72)	—	—	—	—	—	—	—	—	—	—															

* Fair colored hair. † The ash of these articles was not included in the analysis of the 100 parts, but is added to show the proportion of inorganic to the organic matter. ‡ This analysis is from the muscular fibre of beef. It contains, in its natural state, 77 per cent. of water and 23 of dry animal matter. The blood contains 79 of water and 21 of dry matter, and the skin 58 of the former to 42 of the latter.

TABLE IX.

Analyses giving the proportions, in per cents, of the Organic Elements in the Proximate Constituents of Vegetable and Animal substances.

NAMES OF THE ORGANIC ELEMENTS.	Proximate Constituents														
	Butter. <i>a</i>	Glycerin. <i>k</i>	Stearin. <i>l</i>	Margaric Acid. <i>m</i>	Oleic Acid. <i>n</i>	Sperm Oil. <i>c</i>	Olive Oil. <i>d</i>	Linseed Oil. <i>e</i>	Nut Oil. <i>e</i>	Castor Oil. <i>e</i>	Beeswax. <i>d</i>	Rosin. <i>f</i>	Bitumen. <i>g</i>	India Rubber. <i>h</i>	Gum Camphor. <i>i</i>
Carbon, - - -	65.60	39.44	76.60	75.55	76.73	78.91	77.21	76.01	79.77	74.17	81.79	83.7	82.2	87.2	79.2
Hydrogen, - - -	17.60	8.73	12.29	12.55	11.89	10.97	13.36	11.35	10.57	11.03	12.67	11.5	14.8	12.8	10.4
Oxygen, - - -	16.80	51.83	11.11	11.90	11.38	10.12	9.43	12.62	9.12	14.78	5.54	4.8	-	-	10.4
	100	100	100	100	100	100	100	99.98	95.46	99.98	100	100	97.0	100	100

a Berard.*c* Ure.*h* Farraday.*k* Pelouze.*d* Gay Lussac and Thenard.*i* Dumas.*l* Liebig.*m* Erdmann.*n* Sausure.*o* Liebig.*p* Bousingault, page 144.*q* Erdmann.*r* Thompson.*s* Varrentrapp.

TABLE X.

Analyses, in per cents, contrasting the Proximate constituents of Vegetable and Animal substances.

NAMES OF THE ORGANIC ELEMENTS.	OF VEGETABLE ORIGIN.						OF ANIMAL ORIGIN.								
	1. Fibrin. a	1. Albumen. a	1. Casein. a	Gluten. a	Pectine. c	1. Starch. d	5. Proteine. b	4. Legumine. a	Fibrin. a	2. Albumen. b	3. Casein. a	6. Protein. b	7. Gelatine. b	8. Chondrin. b	9. Pepsin. e
Carbon, -	53.23	53.74	53.46	53.27	42.9	44.26	54.99	50.46	52.78	54.84	53.50	54.41	50.04	49.96	57.7
Hydrogen, -	7.01	7.11	7.13	7.17	5.1	6.70	6.87	6.65	6.96	7.09	7.05	6.95	6.47	6.63	5.6
Nitrogen, -	16.41	15.66	16.04	15.94	—	—	15.66	18.19	16.78	15.83	15.77	16.05	18.36	14.44	21.0
Oxygen, -	—	—	—	—	52.0	49.04	22.48	—	—	21.23	—	—	22.56	25.13	28.59
Sulphur, -	23.35	23.50	23.37	23.62	—	—	—	24.70	23.48	0.68	—	—	—	—	—
Phosphorus, -	—	—	*	—	—	—	—	—	—	0.33	—	—	—	—	—
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

a Dumas and Cahours. b Mulder. c M. Fremy. d Strecker. e Vogel.

1. From wheat. 2. From serum of blood, (human.) * Phosphate of Lime exists in this article instead of Phosphorus. Cow's milk. 4. From Beans. 5. From vegetable Fibrin. 6. From animal Fibrin. 7. This substance is derived from the parings of hides, hoofs, ears, horns, calves' feet, &c. It is termed size in its impure state, and glue when purified. 8. From cartilages of ribs, joints and larynx, of animals. 9. The most essential part of the gastric juice.

T A B L E X I.

Analyses giving the proportions, in per cents, of the Organic Elements in the Proximate constituents of Vegetables, including Alcohol and Sugar of Honey.

NAMES OF THE ORGANIC ELEMENTS.	Common Wood.*													
	Woody Fibre. b	Arabic Gum. d	Starch. † b	Cane Sugar. b	Starch Dextrine. † d	Starch Sugar. e	Grape Sugar. f	Honey Sugar. b	Alcohol. †	Acetic Acid. h	Tartaric Acid. h	Citric Acid. h	Mallic Acid. § g	Oxalic Acid. † c
Carbon, - - - - -	51.00	42.70	42.80	42.20	44.3	36.1	36.71	36.36	52.17	47.5	36.81	41.49	41.238	26.566
Hydrogen, - - - - -	6.16	6.36	6.35	6.42	6.0	7.0	6.78	7.09	13.31	5.8	3.00	3.43	2.883	2.745
Oxygen, - - - - -	42.09	50.94	50.85	51.38	49.7	56.9	56.51	56.55	34.52	46.7	60.19	55.08	55.879	70.689
	99.25	100	100	100	100	100	100	100	100	100	100	100	100	100

a Payen.

b Prout.

c Gay Lussac and Thenard.

d Berzelius.

e Guerin.

f Saussure.

g Liebig.

h Johnson's

Lectures.

i Dumas and Boullay.

† Dried at 212 c.

‡ Hydrated.

§ Anhydrous.

|| Dried in vacuo.

* Average of the analyses of the three varieties.

T A B L E X I I.

Analyses giving the proportions, in per cents, of the Organic Elements in the Proximate constituents of Vegetable substances, which are poisonous, medicinal, or nutritive.

NAMES OF THE ORGANIC ELEMENTS.	Prussic Acid. a	Nicotine. b	Strichnine. c	Solanine. e	Picrotoxine. g	Conia. b	Emetina. f	Atropia. c	Veratria. d	Morphia. c	Quinine. c	Piperinc. h	Caffeine. c	Theine. c	Blue Indigo. i
Carbon, - - - -	44.573	26.76.36	76.36	62.11	60.26	76.45	64.57	70.98	70.786	72.340	75.76	71.94	49.77	50.101	73.28
Hydrogen, - - - -	3.7	9.65	6.51	8.92	5.70	12.48	7.77	7.83	7.636	6.366	7.52	6.56	5.33	5.214	3.82
Nitrogen, - - - -	51.8	17.09	8.04	1.64	1.37	11.07	4.30	4.83	5.210	4.995	8.11	4.90	28.78	29.009	10.69
Oxygen, - - - -	-	1	9.09	27.33	32.74	-	22.96	16.36	16.368	16.299	8.62	16.60	16.12	15.676	12.21
	100	100	100	100	100	100	99.60	100	100	100	100	100	100	100	100

a Brande, p. 614. b Ortigosa and Barral. c Liebig. d Couerbe. e Blanchet. f Pelletier. g Francis. h Regnault. i Dumas.
Prussic acid, from almond, plum and peach kernels, &c. Atropia, from the *atropa belladonna*, or *deadly nightshade*—a deadly poison.

Nicotine, from *tobacco*—a deadly poison.

Strichnine, from *strychnos, nux-vomica*, &c.—active poison.

Solanine, from *potatoes*, especially young sprouts, and a few other vegetables—active poison.

Picrotoxine, from *cocculus indicus*, or fish berries—active poison.

Conia, from the *hemlock*—virulent poison.

Emetina, from *ipecacuanha*—an emetic in small portions, and a poison in large ones.

Veratria, from the *white hellebore*, or *veratrum album*—extremely poisonous.

Morphia, from opium—narcotic poison, and medicinal.

Quinine, from Peruvian bark—medicinal.

Piperinc, from black pepper.

Caffeine, from coffee.

Theine, from tea.

TABLE XIII.

Analyses giving the proportions of Organic Elements in several substances, showing their relative value as manures, with the proportion of Ashes in a part of them.

ORGANIC CONSTITU- ENTS AND ASH.	Oak.	Beech.	Walnut.	Wheat Straw.	Hay.	Rotting Oak.	Humus.	Umic Acid.	Humic Acid.	Urea.	Uric Acid.	EXCREMENT. †			Human Faeces.
												Cow.	Horse.	Pig.	
Carbon, -	50.00	49.25	51.92	48.48	45.8	47.6	72.3	57.00	63.0	20.0	36.08	39.8	38.6	38.7	45.24
Hydrogen, -	6.20	6.10	5.96	5.41	5.0	6.2	6.2	4.75	6.0	6.6	2.44	4.7	5.0	4.8	6.88
Nitrogen, -	-	-	-	0.35	1.5	-	-	-	-	46.7	33.36	2.6	2.7	3.4	4.00
Oxygen, -	43.80	44.65	42.12	38.79	38.7	44.9	21.5	38.25	31.0	26.7	28.12	35.5	35.4	32.5	30.30
Ashes, - -	-	-	-	6.97	9.0	1.3	-	-	-	-	-	†17.4	†17.3	†20.6	13.58
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

† Salts and earths.

† The excrement includes the urine and dung. Each kind, in drying, lost over 80 per cent. of moisture.

TABLE XIV.

Average proportion of the Proximate Constituents in Grains and Edible Roots, as determined by chemical analysis.

NAMES OF THE PROXIMATE ELEMENTS.	WHEAT.*			BARLEY.			IND. CORN.†		Rye.*	Oats.*	Carolina Rice.*	Buckwheat.†	Beans.†	Peas.*	Sweet Potato.†	Red Potato.†
	Bran.	Flour.	Wheat.	Unmalted.‡	Malted.‡	Meal.‡	Yellow.	White.								
Woody fibre,	45.7	—	7.5	—	47.29	11.96	18.01	e 6.0	d 21.7	5.1	f 14.42	f 7.0	e 11.0	—	—	—
Starch,	—	73.2	63.2	32.0	56.0	67.18	49.22	40.34	64.0	46.1	89.5	42.47	43.0	47.0	15.1	15.0
Sugar,	—	65.6	—	5.0	15.0	5.21	6 9.55	8.80	a 3.0	a 6.1	a 0.3	b 6.16	0.2	a 2.0	—	—
Gum.	28.8	4.2	12.4	4.0	15.0	4.02	—	—	a 3.0	a 6.1	a 0.3	b 6.16	0.2	a 2.0	—	—
Albumen,	—	—	—	—	—	—	—	—	11.0	3.8	0.7	g 1.60	1.5	5.0	—	—
Gluten,	—	20.0	13.4	14.3	3.0	1.0	3.52	3.40	11.0	3.8	0.7	g 1.60	1.5	5.0	—	—
Dextrine,	—	—	—	—	—	—	—	—	10.5	13.7	3.8	—	—	—	—	—
Legumin,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Horden,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fatty matter,	—	5.5	2.1	1.6	55.0	12.0	—	—	—	—	—	—	k 23.6	20.4	—	—
Casein,	—	—	—	—	j 1.0	1.0	—	i 3.71	i 4.68	6.7	0.2	i 0.47	e 0.7	2.0	—	—
Phosphate of Lime,	—	—	—	—	—	—	—	0.75	0.51	—	—	—	—	—	—	—
Water,	—	—	—	—	—	—	—	0.24	—	—	—	—	—	—	—	—
Loss,	—	—	—	—	—	—	—	9.37	14.00	0.4	—	n 10.10	—	m 3.0	—	—
Ashes,	—	—	—	—	—	—	—	1.42	—	—	—	o 2.66	p 1.9	—	—	—
	100	100	99	100	100	100	100	99.80	99.82	100	98.0	100	98.24	100	98.4	102.5

* Boussingault, pages 177, 178, 182, 188.

† Dr. Salisbury, Albany, N. Y.

‡ Kimhoof and Lam-pautius.

§ Pronst.

|| Einhoof.

a Starch, sugar, or *glucose*. b Sugar and extractive matter. c Woody fibre, including salts, phosphates. d Including ashes and loss. e Including pectic acid. f Epidermis. g Dextrine or gum. h Including gluten, starch, and lignin. i Oil. j Resin. k Legumin, albumen, &c. l Oil and fat. m Salts and phosphates. n A light grey matter taken up by a weak solution of caustic potash from the bodies insoluble in water and boiling alcohol. o Matter dissolved out of the bodies insoluble in water, by boiling alcohol; rising with a substance analogous to water. p Salts and loss.

TABLE XV.

Average proportion of the Proximate Constituents in ripe and unripe Fruits, as determined by chemical analysis.

NAMES OF THE PROXIMATE ELEMENTS.	PLUMS.†		APPLES.*		PEACHES.*		CHERRIES.*		PEARS.*		GOOSE-BERRIES.*		APRICOTS.†		
	Green.	Ripe.	Fresh.	Dried.	Unripe.	Ripe.	Unripe.	Ripe.	Ripe and Fresh.	Kept for some time.	Unripe.	Ripe.	Green.	Riper.	Ripe.
Woody fibre, -	1.26	1.11	3.203	19.0879	3.61	1.86	2.44	1.12	3.80	2.19	8.45	8.01	3.61	2.53	1.86
Sugar, -	17.71	24.81	a 8.325	a 49.7627	trace	16.48	1.12	18.12	6.45	11.52	0.52	6.24	trace	6.64	16.48
Gum, -	5.53	2.06	-	-	-	-	-	-	-	-	-	-	-	4.10	5.12
Albumen, -	0.45	0.28	1.379	8.3720	0.76	0.17	0.21	0.57	0.08	0.21	1.07	0.86	0.76	0.34	0.17
Gluten, -	-	-	b 0.194	b 1.1463	-	-	6.01	3.23	-	2.07	1.36	0.78	-	-	-
Dextrine, -	-	-	3.144	18.6805	4.10	5.12	1.75	2.01	3.17	2.07	1.80	2.41	2.70	2.30	1.80
Casson, -	-	-	0.164	0.9921	2.70	1.80	-	-	0.11	0.08	0.12	0.31	trace	trace	-
Malic acid, -	0.45	0.56	0.317	1.9585	trace	trace	0.14	0.01	0.03	0.04	0.24	0.29	trace	trace	trace
Citric acid, -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lime, -	trace	trace	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorophyl and coloring matter, -	0.03	0.08	-	-	0.04	1.10	0.05	-	0.08	0.01	0.03	-	c 0.04	c 0.03	c 0.10
Water, -	74.57	71.10	82.664	-	89.39	74.87	88.28	74.85	86.28	83.83	86.41	81.10	89.39	84.34	74.87
Loss, -	-	-	0.610	-	-	-	-	-	-	-	-	-	-	-	-
	100	100	100	100	100	101	100	99.91	100	99.95	100	100	100	100	100

* Analyzed by J. H. Salisbury, M.D., Albany, N. Y.

a Sugar and extract.

c Coloring matter.

† Beard.

b Glutinous matter, with a little wax and fat.

TABLE XVI.

Chemical analyses of certain soils, showing what constitutes productive and what unproductive lands.

CONSTITUENTS OF THE SOILS.	1	2	3	4	5	6	7	8	9	10	11	12
	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Soil.	Subsoil.	Soil.	Soil.	Soil.
Silica, with siliceous sand, -	n 90.221	n 92.324	o 95.698	o 96.880	o 95.343	o 95.180	n 87.859	o 94.274	o 95.146	o 95.841	o 86.200	n 64.800
Alumina, -	2.106	2.262	0.504	0.890	0.600	1.600	2.652	1.560	1.416	0.600	2.000	5.700
Peroxyd and protoxyd of Iron, -	3.951	2.914	2.496	1.496	1.800	2.200	5.132	m 2.496	m 2.528	1.800	m 2.900	l 6.100
Peroxyd of Manganese, -	0.960	2.960	trace	trace	trace	trace	k 0.480	0.240	0.320	trace	0.100	0.090
Lime, -	a 0.538	0.532	0.098	0.019	h 0.088	0.455	1.459	0.400	0.297	h 0.038	—	5.880
Magnesia, -	b 0.730	0.340	0.147	0.290	h 0.006	0.160	h 0.280	0.230	0.221	h 0.006	0.520	0.840
Potash, -	0.067	0.304	f 0.090	f 0.079	0.005	0.004	f 0.090	0.102	0.060	0.002	0.095	f 0.210
Soda, -	0.010	trace	g 0.164	g 0.110	g 0.198	0.400	g 0.505	—	—	g 0.198	0.020	u 0.430
Phosphoric acid, -	0.367	0.122	c 0.007	trace	0.002	trace	l 0.068	0.039	—	0.002	0.021	u 0.210
Sulphuric acid, -	c trace	0.010	—	—	—	—	—	—	—	0.002	—	u 0.430
Carbonic acid, -	—	—	d 0.010	trace	0.006	0.001	d 0.006	0.005	trace	—	0.010	u 3.920
Chlorine, -	—	—	0.846	0.226	1.000	—	1.109	0.210	—	1.504	3.370	d 0.201
Humus, -	0.900	0.004	—	—	—	—	—	0.444	—	—	0.544	5.600
Humus insoluble in alkalies, -	—	—	—	—	0.502	—	—	—	—	—	—	j 2.540
Water, -	—	—	—	—	—	—	—	—	—	—	—	1.504
Loss, -	0.140	0.228	—	—	—	—	—	—	—	—	—	r 1.582
	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.

a Lime principally combined with k With protoxyd, phosphoric acid and humus. b With silicate of potash, &c. c In gypsum. d In common salt. e And azotized matter. f The greatest part in combination with silica. g Phosphate of Iron. h In combination with silica. i Soluble in alkalies. 1, 2. Remarkably suited for *leguminous* plants, with gypsum added. 3, 4. Well fitted for *leguminous* plants and clover, with lime and ashes added. 5, 6. Characterized by great sterility, from want of lime, potash, magnesia and gypsum. 7. Crops of grain on this soil always affected by rust. 8, 9. Celebrated for its beautiful crops of clover, rye, potatoes, and barley. The clover always, however, must be manured with gypsum. 10. Eminently sterile, but improved by the alkalies. 11. Remarkable for being manured only once in 10 or 12 years, and bears beautiful wheat as a last crop. 12. Cultivated in corn for 70 years and never manured, but occasionally *substituted*.

T A B L E X V I I .

Chemical constituents of articles of great value as manures.

Urine of Cow.		Human Urine.		Guano.*		Bones.*	
Silica, - - - - -	0.4	Silica, - - - - -	trace	Water, salts of ammonia, and organic matter, expelled by red heat, - - -	23.5	1.	Organic matter, 43.3
Potash, - - - - -	6.6	Sulphate of Potash, - - -	3.7	Sul. of Soda, - - -	1.8	Phos. of lime, - - -	50.6
Soda, - - - - -	5.5	Fluoride of Calcium, - - -	3.2	Common salt, with a little soda, - - -	30.3	Car. of lime, - - -	4.5
Lime, - - - - -	0.6	Phosphate of Mag. - - -	trace	Phos. of lime, with a little phosphate of magnesia and carbonate of lime, - - -	44.4	Magnesia, - - -	0.9
Magnesia, - - - - -	0.4	Phosphate of Lime, - - -	1.1			Soda, - - - - -	0.3
Oxyd of Manganese, - - -	0.1	Phosphate of Soda, - - -	2.9			Potash, - - - - -	0.2
Oxyd of Iron and Alumina, - - - - -		Phosphate of Am. - - -	1.6			From Ileum of a sheep, - - -	99.8
Sulphuric acid, - - - - -	4.0	Common salt, - - - - -	4.5				
Phosphoric acid, - - - - -	0.7	Sal-ammoniac, - - - - -	1.5				
Chlorine, - - - - -	2.7	Free lactic acid, lactate of ammonia, and animal matter, - - -	17.1				
Carbonic acid, - - - - -	2.1	Urea, (Mucus 0.3) - - -	30.1				
Ammonia, - - - - -	2.1	Uric acid, - - - - -	1.0				
Hippuric & lactic acids, - - -	6.1	Water, - - - - -	933.0				
Urea, - - - - -	40.0						
Mucus, - - - - -	2.0						
Water, - - - - -	925.2						
	1000.0		1000.0		100.0		100.3

* Guano varies much in its composition, owing to local causes and the extent of exposure to which it has been subjected. Bones also differ a little in their chemical constituents, as will be seen from the two analyses given above.

NOTE BY THE AUTHOR.

Owing to the engagements of the author, taking him from home while the work was passing through the press, a part of the proofs could not reach him before the sheets were printed. The reader will please to make the following corrections, which include all of importance that have escaped the proof reader. Small letters instead of capitals, have been used, by mistake of the compositor, in the Generic names of vegetables.

Page 35, 11th line from bottom, for 'seicome,' read 'leicome.'

Page 53, 4th line from top, for 'feet,' read 'fat.'

Page 60, 10th line from bottom, for 'beating,' read 'heating.'

Page 113, line 18 from bottom, for 'organism,' read 'organisms.'

Table II, in figures of Grain of Oats, opposite Oxyd of Iron, read '0.40,' instead of '0.70.'

Table V, under Outside Wood of Chestnut, opposite Phos. of Peroxyd of Iron, read '1.30,' instead of '0.30,' and under Wood of Peach tree, opposite Sulphuric Acid, read '1.51,' instead of '0.51.'

Table VII, under Rye, opposite Hydrogen, read '5.38' and '5.58,' instead of '5.58' and '5.38,' and same line, under Peas, read '6.09,' instead of '6.69.'

Table IX, in figures of Nut oil, in footing, read '99.46,' instead of '95.46.'

Table X, in foot note, fig. 3 omitted before 'cow's milk.'

Table XIV, in figures of beans, opposite Loss, read '1.0,' instead of '1.9,' and in 2d line of Notes, for 'Starch, sugar,' read 'Starch-sugar.'

